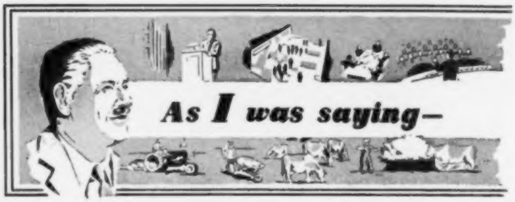
Metal Progress

December 1952

IN THIS ISSUE

A Christmas greeting from ASM headquarters is conveyed by this month's cover, designed and executed by *Metal Progress*'s art director, Floyd E. Craig



I WOULD BE nicknamed "Polly" if I repeated all the fine statements made about the 34th Metal Congress and Exposition held in Philadelphia. All of the thousands of ASMers in attendance were pleased beyond words and certainly took great pride in the fact that they were members of the Society. Beginning on Saturday with the Seminar, and continuing through the last session on Friday, every moment was filled with activity, the stimulating effects of which will last for a long time.

The clocked attendance was 78,863 while the individual registration numbered 43,301 — by all odds the largest attendance and enrollment in A.S.M.'s history. This column is too brief to give all the details. Many have already been presented in *Metals Review* and in "Critical Points" in this issue of *Metal Progress*, so I'll hit lightly the peaks of (1) attendance (see above), (2) decor, (3) the royal carpet, (4) Young Engineers' Day, (5) the exhibits.

2. The decor was novel and marks the beginning of a new phase in which metals constitute the medium for the decorations. There were mobiles, crystalliers, stabiles, diamonds, disks, expanded metal screens, modern sculptures — all helping to get away from cloth decorations, the old standby for 33 years. The fine decor blended into an ensemble and proved that art and industry can dwell together.

3. And to top it all, the two miles of aisles of the Show were covered with a 5-ft. wide strip of royal red, foam-rubber-backed carpet which eased the steps of the customers and became, in fact, the sensation of the Show. It reduced fatigue, added to the Show's appearance, and since the carpet is owned by A.S.M., it will be used again in future shows.

4. Some 1974 college students from 25 engineering schools within 150 miles of Philadelphia spent an interesting and enlightening day at the Metal Exposition on Friday, Oct. 24. These young engineers have written to headquarters about the wonderful day they experienced; the presidents and deans of engineering have been loud in their praises of the Society's action in presenting this opportunity to the students. Surely the metals industry will experience less difficulty in securing its 50% quota of these engineers upon graduation. And the A.S.M. — the engineering society of the metals industry — has again been pleased to serve the metal producing and fabricating industry.

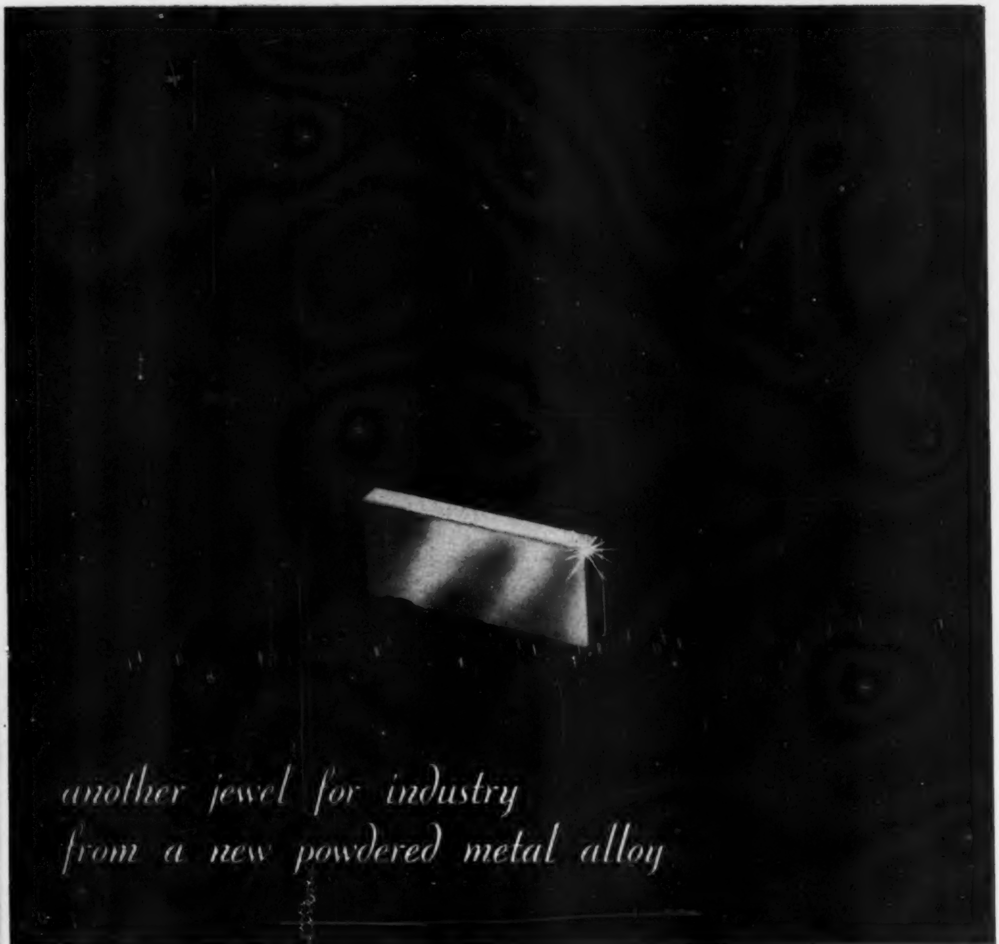
5. The exhibit staggered description. Never were so many exhibits (426) on such varied products used in metal producing and metal processing displayed under such scintillating circumstances. The visitors thronged the booths, studied the exhibits, and placed their orders.

It was a great occasion — the best in business ever. On all sides they ask, "What are you going to do next?" Well, here it is: I'm going to wish a Merry, Bright and Happy Christmas to all of you and yours from all of us.

Cordially,

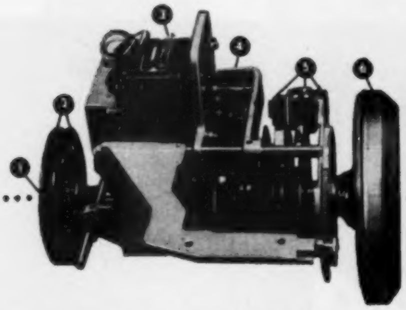
Bill

W. H. Eisenman, *Secretary*
American Society for Metals



R-265

1. Center line of slidewire and shaft
2. Control cams
3. Balancing motor
4. Spring-loaded no-backlash drive
5. Control slidewires
6. Measuring slidewire

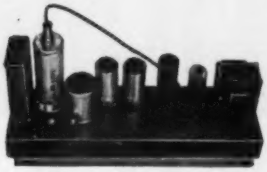


POWER IS PERFORMANCE

... and Speedomax Instruments lead with "huge" 12-watt balancing motors!

This partially dis-assembled view of Speedomax shows its two-phase Balancing Motor and gears, with a typically "heavy" load of slidewires and contacting cams for signal and control devices. Several more cams, etc., can be added if necessary; only practical limit is physical space on shaft. Smoothness in operating many contacts is an outstanding Speedomax ability.

Amplifier which feeds the Speedomax balancing motor the controlling half of its power. Torque gradient is especially high where needed most—around balance point—for prompt, positive balancing. This Amplifier leads its field by large margins in sensitivity and in power output.



Good circuit engineering shows in this Slidewire's non-inductive wiring and in the absence of any flexible leads which might form inductive loops.

• Power underlies good performance, in instruments as in automobiles, machine tools or rolling mills. That's why L&N engineers insist that an automatic instrument should operate as positively and promptly as any other high-grade machine.

Even the first null balance potentiometer Recorder we built, back in 1911, which went to a steel mill, had a 110-volt motor instead of a spring drive to run its balancing mechanism, chart and signalling contacts. And, while its pioneering of balance-method measurement attracted the most attention, its ample power certainly helped establish L&N Recorders as the coming idea in process Instrumentation.

Power has done the same for Speedomax instruments. Twenty years ago, Speedomax pioneered the electronic idea of measurement—in a husky, powerful piece of equipment. Today's models have from 2 to 4 times more power in their balancing motors than any other current models of electronic controllers, recorders or indicators.

This power means superior performance in both load-carrying and speed. Load-carrying ability applies especially when the motor operates, in addition, an unusual number of contact devices. But even the most usual Speedomax jobs—automatic control, for instance—can call on the instrument's power for high operating speed in handling the normal number of control devices. The strong, wide-faced, rigidly-mounted cams and gears so typical of Speedomax instruments start moving instantly, move rapidly and stop dead still without coast. Signalling and control action is correspondingly crisp and precise.

Speedomax for industrial use is described in Catalog ND46 (1); additional information for unusual applications is given in Technical Publication ND46(1). Either will be sent on request by our nearest office or from 4927 Stenton Ave., Philadelphia 44, Pa.

CAREER OPPORTUNITIES AT L&N

Expansion program of this long-established firm has many features to attract outstanding recent graduates in engineering and science. Opportunities are in sales field engineering, product and application engineering, research, advertising, market development. Widely-respected policies assure recognition of progress and achievement. Address Personnel Manager for preliminary interview at nearest of 17 L&N offices.

LEEDS & NORTHRUP

instruments · automatic controls · furnaces

Jrl. Ad. ND46(8)

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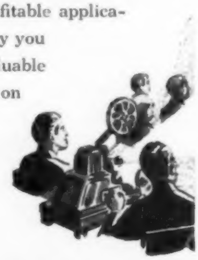

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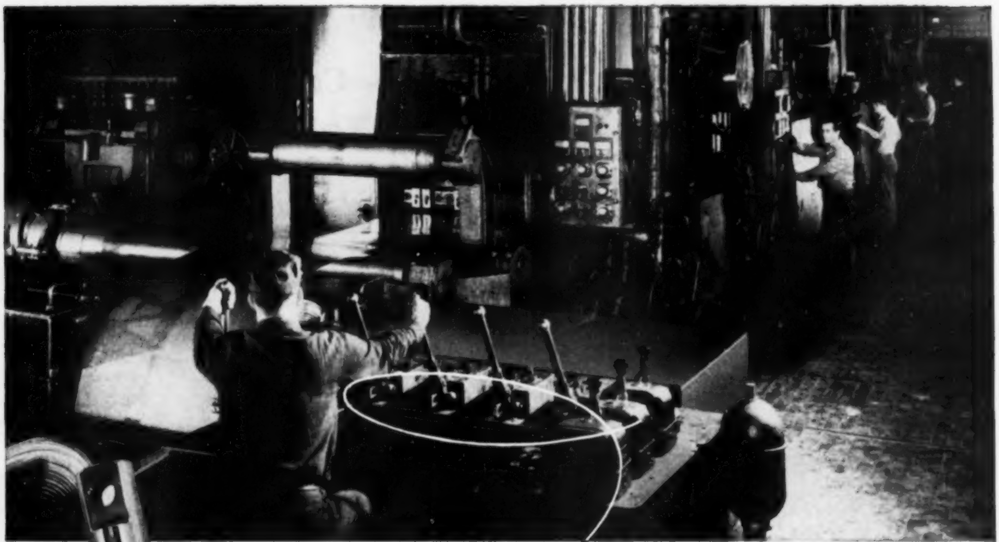

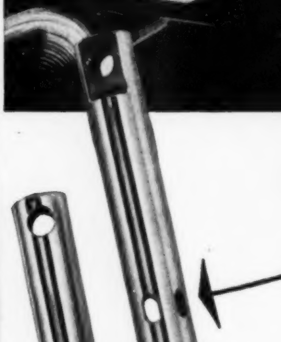

Free-Machining ENDURO Helps Control Stainless Machining Costs

In pneumatic and hydraulic control valves, ENDURO Stainless Steel plungers help boss big mills like this . . .

The ENDURO plungers—through which air, water, and oil flow under thousands of pounds pressure — must resist corrosion, resist abrasion, and maintain a tight seal at all times. They must be fully balanced so that they cannot creep or crawl.

All this requires a lot of machining . . . upwards of 30 separate operations. Free-Machining ENDURO Bars are cold finished by Republic's Union Drawn Division especially for efficient, economical production of all such highly-machined parts. They provide close tolerances, accuracy of section, uniform soundness, and fine surface finish, together with the high physical and chemical properties of stainless steel. Two grades are 90% as machinable as Bessemer screw stock.

Free-Machining ENDURO also is available in hot rolled bars, and in wire. Republic metallurgists are ready to give prompt assistance on applications, processing and use. Write:

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.

Half-inch and three-quarter-inch plungers for Hunt "Quick-As-Wink" control valves are machined from Type 416 Free-Machining ENDURO Stainless Steel by C. B. Hunt & Son, Inc., Salem, Ohio.

Republic ENDURO® FREE-MACHINING STAINLESS STEEL
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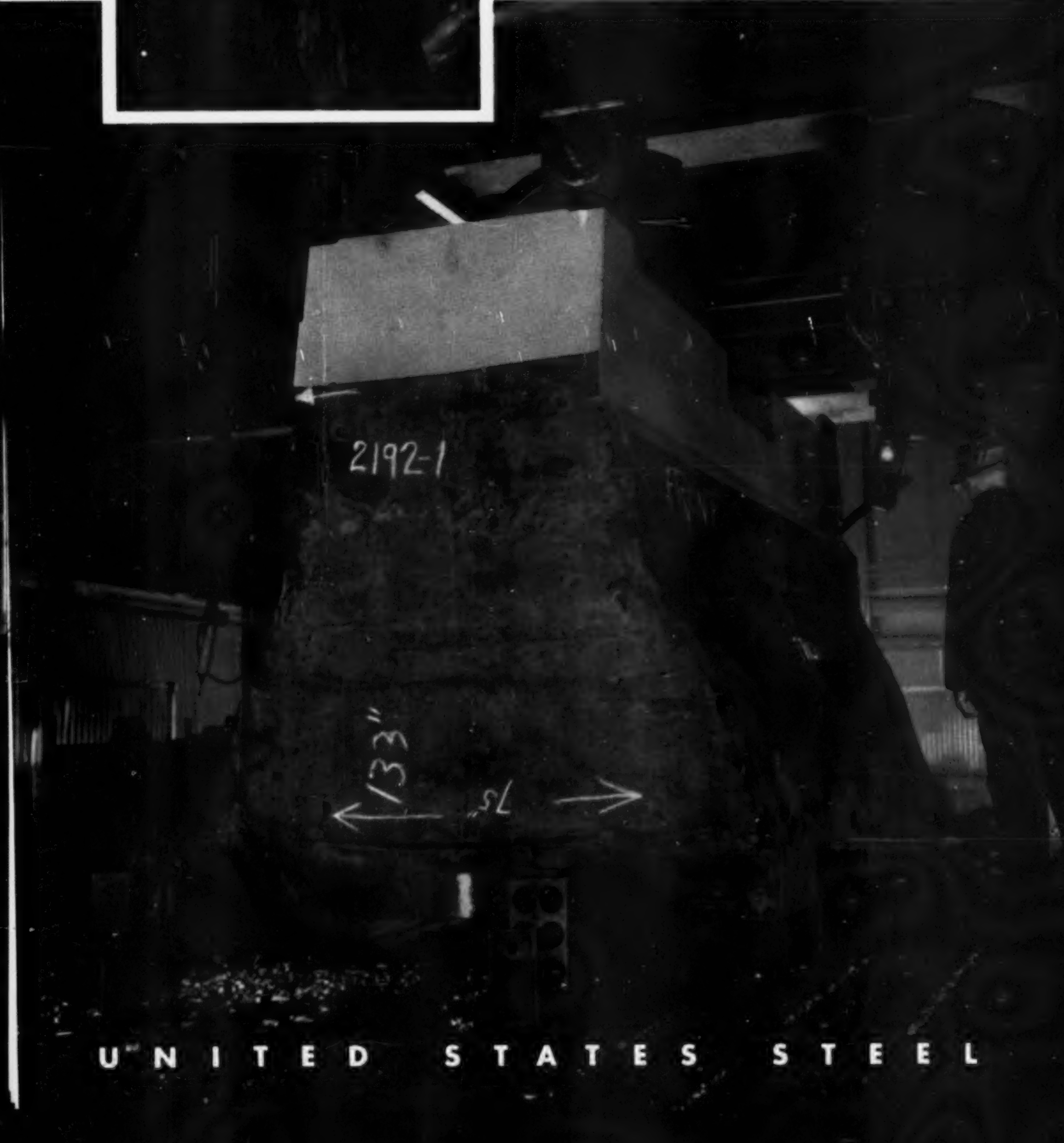
Other Republic Products include Carbon and Alloy Steels—Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing


FROM THE TOP STEEL PRODUCER . . .
TO A LEADING CHEMICAL HOUSE,
A YEAST COMPANY
AND A MEAT PACKER . . .


if it has to do with
x-ray
it has to do with
PICKER
x-ray

"We know how

says George Sumner,



UNITED STATES STEEL

to handle big ones like this"

UNITED STATES STEEL MACHINIST

● The man in the picture is Machinist George W. Sumner, who has worked in the Forge Department of our Homestead District Works for 43 years. After the steel has been poured, heated, forged, heat-treated and inspected many times—George sets it up on his 15-foot planer and goes to work.

If you asked him to tell you about it in his own words, the conversation might go something like this:

YOU: "*That's a mighty big forging you've got there. What is it?*"

SUMNER: "It's a forged anvil base for a large drop hammer. We started off with a 500,000-pound ingot, but when I'm through with it, it'll ship out at around 300,000 pounds. Right now, it's 14 feet long, 6 feet wide, and 7 feet high."

YOU: "*Must be quite a job handling it on the planer.*"

SUMNER: "Well, it's not exactly child's play. Setting it up correctly is very important. The weight must be spread out properly, because even on this big machine we work down to a few thousandths of an inch."

YOU: "*But once you've made the set-up, the planer runs automatically, doesn't it?*"

SUMNER: "Sort of, but no planer knows how to think. Take lubrication for instance. We have an automatic oil pump, gages and all that. But when you're cutting the short side of a piece, the table only takes a short stroke, and part of the ways don't get oil. If you keep that up, the ways get hot and they warp, and your accuracy is gone. So the operator—that's me—solves the problem by taking long strokes every once in a while, to spread the oil."

YOU: "*In your opinion, what's the secret of making good forgings?*"

SUMNER: "Good steel to start with—and good equipment to work it on. We have both. Then you've got to know what you're doing and take time enough to do it right. You can't leave anything to chance. That's the only way you can be sure your customer will get what he's ordered—a *quality* forging.

• • •

When you buy forgings from United States Steel Company, highly skilled men like George Sumner will work on them. We will match their knowledge and experience against the best in the land. For more information on U·S·S Quality Forgings, write to United States Steel Company, 525 William Penn Place, Room 2806-T, Pittsburgh 30, Pa.

USS

Quality

FORGINGS

Your Stamping Ground for new products

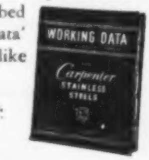
with Carpenter Stainless

• Let's say you have a really good idea for an improved product in 195*X*. But there's just one hitch. You will need a Stainless Steel that has a combination of properties different from any Stainless ever made.

You might need the rustproof qualities of Stainless *combined with* special hardness limits to control spring-back of formed parts. Or, special tolerances combined with extreme ductility might be your answer to producing that good idea at a profit.

The job shown here was just that ticklish, when someone said, 'Let's call Carpenter'. If that sounds 'too easy' a way to solve a Stainless engineering problem, try it yourself. Drop us a line about your future products and the special things you would like Stainless Steel to do for you.

Doing the unusual with Stainless is a habit here at Carpenter. For example, one new steel is Carpenter Stainless No. 10, a chrome-nickel grade with an exceptionally low rate of work hardening. Maybe it has a place in your future planning, to solve the problem of cold working that can add to fabricating costs. Stainless No. 10 and many other Carpenter Stainless Steels are described in our 'Working Data' book. Would you like a copy?



The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Dept.: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO"

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"PLUS-ENDURANCE"

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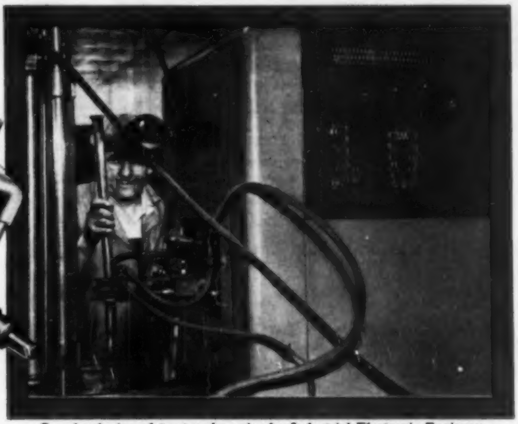
Federal's F-892

(F-892-R Air-cooled)



Case hardening of tractor shoe pins by Industrial Electronic Engineering Corp., Milwaukee, Wis., using 20 KW Allis-Chalmers induction heating unit equipped with Federal's rugged and reliable F-892 power triode.

OUTSTANDINGLY DEPENDABLE IN MOMENTARY OVERLOADS

SEALING, soldering, brazing, bonding, molding, annealing, drying, pre-heating . . . *whatever* your electronic heating application . . . Federal's re-designed F-892 power triode really keeps production lines rolling . . . *by reducing time-wasting shut-downs for tube replacements!*

Incorporating Federal's new *Double Helical Filament* (which eliminates filament-to-grid shorts) the F-892 has been especially designed to withstand the hard punishment of sudden and extreme load changes . . . to resist mechanical shock and steady vibration . . . to stay on the job *longer* . . . under the toughest conditions.

Back up *your* induction or dielectric heaters with the ruggedness and *plus*-endurance of Federal's F-892. Its proved-design assures you the highest operating efficiency for 10 and 20 KW equipments . . . with *lower* tube costs through *longer* life and *fewer* replacements!

Write today for full information on Federal's F-892 or F-892-R.

"Federal always has made better tubes"

First with the new proved-design

DOUBLE HELICAL FILAMENT

- Does away with bowing
- Eliminates filament-to-grid shorts
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Engineering Digest

OF NEW PRODUCTS

TUMBLING BARREL: A new tumbling barrel has been developed by the Globe Div., Hupp Corp., for deburring and burnishing all types of ferrous and nonferrous precision parts. Conventional tumbling action is magnified due to the restrictive nature of the flash-shaped design. Any type of deburring and burnishing material may be used in the machine and it

will handle loads ranging to 750 lb. The barrel is constructed of continuous welded sections of heavy steel plate. A 1/4-in. lining of rubber or neoprene gives longer life to the barrel shell and protects parts. Direct drive is provided with a 1 hp. motor. The tilting angle of the barrel may be adjusted to produce a smooth tumbling action or a more violent one.

For further information circle #1675 on literature request card on p. 32B

THERMOCOUPLE PARTS: Standard graphite taper plugs, threaded end bushings and sleeves for thermocouples are furnished by National Carbon Co. Three sizes of standard tapered plugs are available. While special sizes will be made, standard plugs are lower in cost, are stocked for immediate shipment and are made to gage to assure uniformity of taper. Graphite threaded end bushings are made to purchaser's drawings only. Six sizes of graphite sleeves are offered. They are used bare, requiring no coating of refractory cement.

For further information circle #1676 on literature request card on p. 32B

POROSITY MEASUREMENT: A method for measuring the porosity of metal castings, capable of accurately determining leakage rates as low as 10^{-5} cu.ft. per sq.in. per hr. at one atmosphere of pressure, has recently been developed at Sam Tour & Co. The method was devised in order to measure the effectiveness of a plastic impregnant in reducing the porosity of aluminum castings to be used in high vacuum installations. The new technique is based upon trapping and weighing the quantity of carbon dioxide passing through the test plate placed between a slightly pressurized chamber and one at atmospheric pressure.

For further information circle #1677 on literature request card on p. 32B

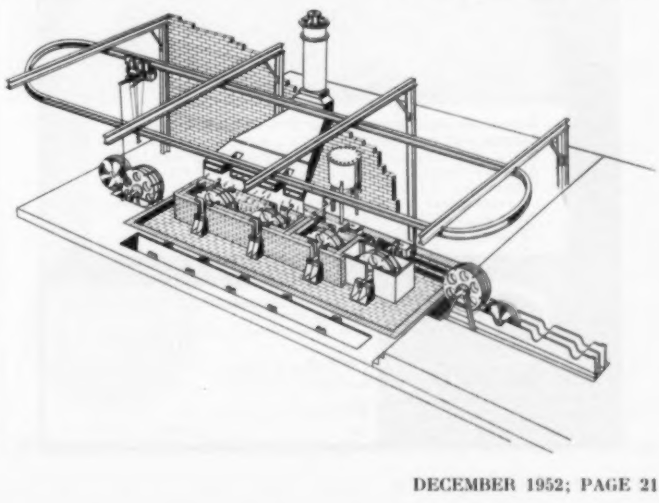
BRONZE ROD AND WIRE: Phosnic bronze, a high-copper alloy containing nickel and phosphorus that makes it particularly well suited for manufacture of springs, clips, high-strength electrical conductors, bolts, nails, screws, cotter pins and many parts where the combination of high strength, high electrical or thermal conductivity, high resistance to fatigue and creep and good workability are required, is being supplied by the Chase Brass & Copper Co., Inc. In this age hardening alloy an aging treatment determines its properties and increases its tensile strength from

PICKLING PLANT: A pickling plant designed for handling 5000 to more than 20,000 tons per year of commercial grades of coiled hot rolled strip in widths from 2 to 24 in. and in gages from 0.042 to 0.188 in. is available to users of coiled strip to enable them to do their own pickling and oiling. This rotary coil pickling plant is being developed in Great Britain, manufactured by the Yoder Co., Cleveland. Coils are loaded into cages and rotated at about 20 r.p.m. in a pickling tank. Uncoiling, scale breaking, loose coiling and pinning are performed by the rotating action of the cages. Thus, revolving the cage in direction opposite to that of the coil windings causes the coil to be unwound wrap by wrap. Reversing the direction of rotation rewinds the coil closely to its original diameter and tightness of winding.

The repeated flexing of the stock in unwinding and rewinding the coil loosens the scale for its removal by the acid. Pickling is completed in 15 to 30 min., depending on strength of the acid. The coil is transferred to the rinse tank where the cage is rotated and the coil unwound. The cage carrying the unwound coil goes to the oil bath for rotation in opposite direction and rewinding to its original size. Average production for load of about 2500 lb. (14-in. strip) is 3 tons per hr., including change of acid every 8 hr.

Tanks are built in tandem and each has a reversible 5 hp. motor to drive the cages. Gear reducers and clutches connect the reducer drive shafts to the respective trunnion shafts of the cages.

For further information circle #1678 on literature request card on p. 32B



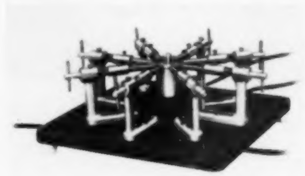
about 38,000 to 65,000 psi, while yield strength is increased from approximately 10,000 to 40,000 psi. After age hardening, Phosnic bronze, unlike some age hardening alloys in the heat treated condition, is suitable for severe cold working of any type. Aged Phosnic bronze wire can be drawn to full spring temper.

Age-hardened and cold drawn Phosnic bronze has greater creep strength than other alloys in comparable tempers including cartridge brass, phosphor bronze or high-silicon bronze. This property makes it particularly well suited for bolt and structural material where high resistance to creep or flow under the influence of prolonged stress is desirable.
For further information circle #1679 on literature request card on p. 32B

TEMPERATURE-HUMIDITY TEST CHAMBERS: A standard line of environmental test chambers for conducting temperature-humidity tests has been developed by Tenny Engineering. These chambers automatically maintain humidity from 20 to 95% through a temperature range of 35 to 185° F. Minimum dew point is 33° F. Five basic chamber sizes are offered and four types of control — constant humidity, constant temperature; constant humidity, varying temperature; varying humidity, constant temperature; and varying humidity and varying temperature.

For further information circle #1680 on literature request card on p. 32B

SOLDERING UNIT: The Wasserlein Mfg. Co., Inc., has announced a new accessory to their Glo-Melt soldering unit, designed for use wherever soldered joints have to be made on cylindrical, rectangular or tubular metal housings. Production figures show that the new device does a more uniform job three to five times faster than hand methods. Because this new unit operates on the principle of resistance soldering, there is no waste (or vaporizing) of flux and no burn, shock or visual arc hazard to the production worker.

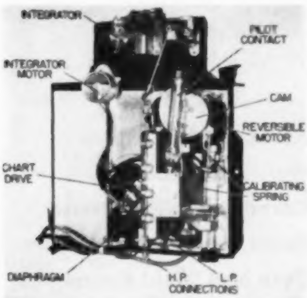


For further information circle #1681 on literature request card on p. 32B

CONTINUOUS CASTING: A machine designed for the continuous casting of tool, stainless and other high grade steels, but adaptable to all ferrous metals, is being installed by Koppers Co. for Atlas Steels. It will yield from 10 to 15% more finished steel per heat than conventional pouring methods. An essential part of the process is the mold oscillation in which the mold moves downward with the casting for a certain distance and then returns quickly. This action keeps the metal from sticking to the mold as it hardens and increases the mold efficiency. With an uninterrupted supply of molten metal, the new

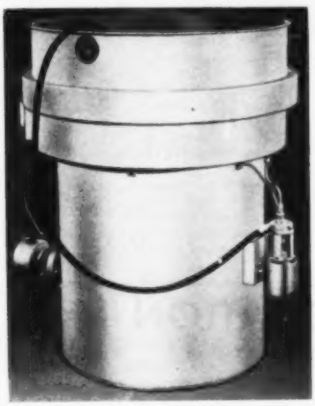
machine would be capable of casting a continuous billet or slab of indefinite length. In actual practice, acetylene torches will cut the metal into usable lengths as it emerges from the casting machine. Continuous casting machines should prove particularly valuable in small and medium size plants as they permit the by-passing of blooming mills and soaking pits.
For further information circle #1682 on literature request card on p. 32B

FLOW METER: The Hays diaflow meter is a new low differential flow meter for measuring air flow, gas flow or recording the ratio of air flow to gas flow. Since it uses a dry diaphragm-type measuring element, no water, oil, or mercury are required and leveling is eliminated. Unit construction, whereby parts can be removed separately or as a whole without affecting calibration, has been



used throughout. The unit in addition to measuring a single flow can be provided with two flow elements so that the gas and air flow records can be combined and coordinated for efficient combustion.
For further information circle #1683 on literature request card on p. 32B

DEGREASER: The new Detrex VS Jr. degreaser is designed to clean



small and medium sized parts and is suited for shops, laboratories and small manufacturing plants where up to 600 lb. of steel per hour must be degreased. Parts are suspended in pure solvent vapor which dissolves dirt and grease. A spray of hot solvent vapor flushes away any loose, stubborn soils which might remain. Finally, a rinse in pure solvent vapor leaves the work clean and dry. Two standard, manually operated models are available. One is electrically heated, the other operates by steam. Both may be relocated in various work areas as long as service facilities are available.
For further information circle #1684 on literature request card on p. 32B

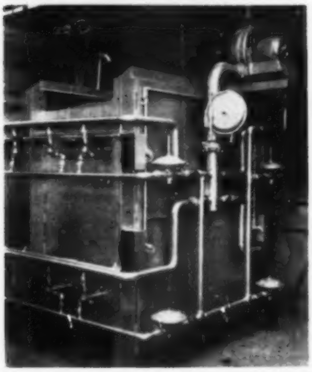
MICROSCOPE: The Zetopan universal research microscope, developed by Reichert and distributed by Wm. J. Hacker, features a monocular-binocular tube permitting instant changeover from binocular observation to microphotography. The object stage is easily accessible to the observer since the arm of the microscope is in the back. The binoculars revolve at a 120° angle, thus permitting a second person to witness the image without interfering with the operator who remains seated. Illumination is built in and examinations may be made by

reflected as well as transmitted light.
For further information circle #1685 on literature request card on p. 32B

CARBON DETERMINATION: A finely divided iron powder, Combax accelerator, is now made available by Fisher Scientific Co. for use as a combustion accelerator in metal analysis. Combax accelerator is added to the sample to be ignited in the induction apparatus when the sample is difficult to fire by induction heating. It is prepared by a hydrogen reduction process which frees it from carbon

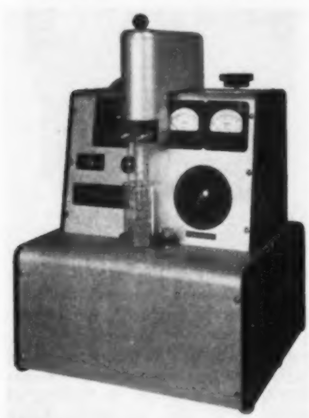
and sulphur impurities. It has an extremely low carbon content (less than 0.01% of carbon per factor weight of 2.727 g.) and negligible traces of sulphur (not more than 0.0025%). Particle size is 50 mesh.
For further information circle #1686 on literature request card on p. 32B

CAR BOTTOM FURNACE: The Waltz car bottom furnace is equipped with special manifolding that permits regulation of the furnace to any desired temperature range and any rate of heating and is primarily designed



to facilitate loading of heavy sections on carburizing boxes. The blower is located at the top with the control valve in the vertical pipe. The air line branches off the vertical pipe to the four groups of burners.
For further information circle #1687 on literature request card on p. 32B

ELECTRO-ANALYZER: The new Eberbach ultra-speed electro-analyzer, a single-position unit, has a produc-

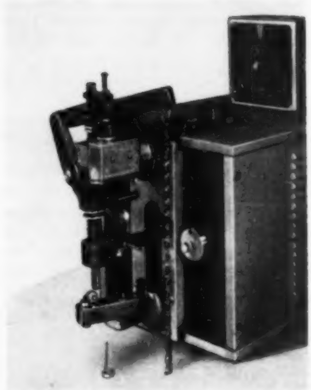


tion rate substantially equal to four positions on conventional apparatus. For example, in a copper assay, an

analytically complete deposition of a 1 g. copper sample is accomplished in 8 min. or less. Best equipment and techniques previously employed require 30 to 60 min. Improved cell design, a unique electro-magnetic field and greater current flow, produce the increased speed.
For further information circle #1688 on literature request card on p. 32B

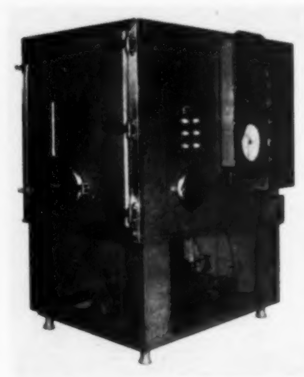
RAPID SPECTROPHOTOMETER: The American Optical rapid scanning spectrophotometer provides instantaneous display of spectrophotographic curves of various materials through the entire visible range of the spectrum. It combines an optical spectrophotometer and electronic indicating device which traces curves at 60 per second on the face of a cathode-ray tube against a linear wave length-percentage grid. Transparent materials up to 100 mm. in thickness can be accommodated, and opaque materials of approximately 1 sq.in. may be examined by means of reflection.
For further information circle #1689 on literature request card on p. 32B

SPOT WELDING AND SOLDERING: Joyal Products, Inc., has announced a new resistance spot welding and soldering machine, equipped with



timer. This machine silver solders, soft solders and spot welds precious and dissimilar metals. It spot welds steel parts up to 3/16 in. thick; spot welds copper to bronze or copper up to 0.040 in. and brass to brass up to 0.080 in. It will solder brass up to ¼ in. thick, as well as sterling silver and other precious metals.
For further information circle #1690 on literature request card on p. 32B

HUMIDITY TESTING: A new humidity testing cabinet with a 27-cu.ft. working area, recently introduced by Murphy & Miller, will supply relative humidity between 20 and 95% in the temperature range 35 to 185° F. Fast, accurate temperature regulation is



assured through the use of a hermetically sealed refrigeration unit and an electric heating system, which quickly lower or raise interior temperatures to the degree required. A high-capacity condensing system anticipates and prevents the forming of moisture on the equipment being tested. Provision is made for testing electrical equipment.
For further information circle #1691 on literature request card on p. 32B

What's new

IN MANUFACTURERS' LITERATURE

1694. Abrasive Wheels
Data folders give operating suggestions and recommended grades of abrasive wheels for finishing stainless alloys. *Manhattan Rubber Div.*

1695. Alloy Steel
68-page "Aircraft Steels" booklet includes revised military specifications. Also stock list. *Ryerson*

1696. Alloy Steel
176-page bound book on hardenability, mechanical properties, heat treatment and applications of alloy steels. 28 pages of tables at end. *U. S. Steel*

1697. Aluminum Castings
8-page description of the mold-making process of Morris Bean, used in production of aluminum castings of highest metallurgical quality. *Morris Bean & Co.*

1698. Aluminum Fasteners
8-page illustrated booklet on all types of aluminum fasteners. Also accessories and screw machine products. *Alcoa*

1699. Aluminum Forgings
168-page book covering relation of forging design to die sinking and to the manufacturing process. Section on metallurgy gives commercial alloy compositions, physical properties and tolerances. *Alcoa*

1700. Aluminum Melting
Folder A-5 describes automatic melting and pouring unit for production of aluminum die castings. *Ajax Eng'g.*

1701. Ammonia
8-page article on applications of dissociated ammonia in powder metallurgy, heat treating, furnace brazing, welding and descaling fields. *Armour*

1702. Analysis
Article on use of direct-reading spectrometer at Kaiser Steel. *Baird Assoc.*

1703. Analysis
Bulletin 130-I on methods for electroanalysis. Extensive bibliography. *Eberbach Corp.*

1704. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

1705. Anodizing Racks
Folder gives data on aluminum racks with copper hooks, insulated for any anodizing solution. *National Rack*

1706. Arc Welders
Illustrated booklets available on both A-C and D-C arc welders. Contain data and diagrams on construction and uses. *Westinghouse Electric*

1707. Atmosphere Furnaces
Information on gas-atmosphere high-production furnace for bright annealing of copper alloys. *Holcroft*

1708. Atmosphere Generators
12-page booklet on gas producers describes equipment and gives data on composition and applications of atmospheres. *Bellevue Industrial Furnace*

1709. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, applications, effects on steel, drawings of generators. *Surface Combustion*

1710. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

1711. Barrel Finishing
55-page book on barrel finishing with Alundum tumbling abrasive. Procedures, practical operating suggestions, and characteristics of abrasive. *Norton*

1712. Barrel Plating
8-page booklet on fully automatic barrel-type plating and processing machines. Automatic methods of loading and unloading. *Frederic B. Stevens*

1713. Barrel Plating
Folder describes equipment for barrel plating with unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply*

1714. Beryllium Copper
Helpful engineering information contained in monthly beryllium copper technical bulletins. *Beryllium Corp.*

1715. Billet Shear
Folder on high-production billet shear with electromagnetic hold-down. *Maddaus Moelders*

1716. Bimetal Elements
64-page book on application of thermostatic bimetal. Property charts for 30 types. Design formulas. *W. M. Chace*

1717. Brass and Bronze
8-page booklet on control methods applied to brass rod, forgings, die castings and welding rod. *Titan Metal*

1718. Brazing
24-page bulletin 20 on advantages of Easy-Flo silver brazing alloy, with information about joint design and fast production methods. *Handy & Harman*

1719. Brazing
50-page text GEA-3193 describes the methods and applications of electric-furnace brazing. *General Electric*

1720. Brazing Shim
Data Bulletin 707A on three-layer sandwich metal for brazing carbide tips to tools. *General Plate*

1721. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

1722. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

1723. Brazing-Alloy Washers
Free sample of silver brazing-alloy preformed washer coined from wire. *Lucas-Milhaupt Engineering Co.*

1724. Bronze, Continuous Cast
12-page bulletin on applications, properties, weights of continuous cast bronze rods, tubes, shapes. *American Smelting & Refining*

1725. Bronze Electrode
Data sheet on phosphor bronze arc welding electrode for phosphor and manganese bronzes. *Weldwire*

1726. Bronzes
Folder gives tables of properties (hardness, tensile, fabrication, physical) as well as uses and forms and other data on Chase phosphor bronzes. *Chase Brass & Copper*

1727. Buffing and Polishing
Catalog A-50 on five-head rotary machine for automatic polishing and buffing of parts from 1/16 to 12 in. diameter. *Hammond Machinery*

1876. Sand Control

A short course in sand technology is offered in "Taking the Mystery out of Foundry Sand Control"*, a recent addition to the manufacturers' literature. The book lists and pictures defects and troubles which signal that something is out of control, establishes the causes and presents the remedies available through sand control.

Sand control — which can be paid for out of savings realized by the scrap reduction it accomplishes — deserves special emphasis in times of high production. First, the proper sands must be selected. The rules for sand selection — type, grain size, shape and composition — are discussed for various metal compositions in the opening sections of the publication. Second, the core and mold mixtures must be prepared to the desired properties. Mixtures, optimum properties and consistent attainment of these properties concern the second portion of the text. Finally, the reader is introduced to the simple but careful testing demanded and the equipment required by the sand control program.

Here is a valuable booklet for everyone concerned with ferrous and nonferrous molding and core making.

*Published by the Claud S. Gordon Co. Copies are available at no charge to readers of Metal Progress who circle No. 1876 on the literature request card on page 32B.

1728. Burners
Bulletin on combination gas and oil burner with high rate of combustion. *Ra-Diant Products Co.*

1729. Burners
Bulletin 1220-5 describes tempered flame burners for controlled heating and cooling cycles. *Bloom Engineering*

1730. Calcium Metal
16-page booklet on properties and potential uses of calcium metal in powder form. *Ethyl Corp.*

1731. Camera Microscope
6-page folder describes universal and compact metallograph with built-in camera. *Wm. J. Hacker*

1732. Carbonitriding
Case history and job data on bright carbonitriding of SAE 1010 levers. *Ipsen*

1733. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

1734. Castings, Bronze
16-page booklet on sand and centrifugal castings. *Amer. Non-Gran Bronze*

1735. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

1736. Cleaning
12-page bulletin on washing and drying machines; conveyor, cabinet, drum and vertical types. *Industrial Systems*

1737. Cleaning
20-page bulletin 214 gives full details, specifications and actual performance on Rotoblast cleaning. *Pangborn*

1738. Cleaning
Pamphlet on properties and use of trichlorethylene. *Niagara Alkali*

1739. Cleaning and Finishing
Catalog A-653 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon Co.*

1740. Cleaning Machines
Bulletin 703 on cleaning machine that agitates and lifts work. *Magnus*

1741. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

1742. Cold Extrusion
Bulletin describes process in which 5-in. dia. steel billet can be cold formed to a cup with less than 1/8 in. wall thickness in three strikes. *Detrex Corp.*

1743. Composite Metal
Data Bulletin 702B on copper-clad aluminum. Properties for six different combinations. *General Plate*

1744. Combustion Control
20-page booklet presents combustion charts for various fuels and describes portable instrument which measures content of oxygen and combustibles simultaneously. *Cities Service Oil*

1745. Combustion Equipment
8-page folder on catalytic fume combustion. *Catalytic Combustion*

1746. Compressors
12-page data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1747. Continuous Casting
24-page book, "Better by the Mile", describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

1748. Copper Alloy Tubes
32-page brochure on causes of corrosion and means of combating them, choice of materials for condenser tubes. *Revere Copper & Brass*

1749. Copper Alloys
See review below. *American Brass*

1750. Corrosion of Copper
24-page booklet B-36 discusses corrosive attack on copper and copper alloys. Includes tabulation of relative corrosion resistance of principal types of copper alloys. *American Brass*

1751. Corrosion Resistance
Single-page technical discussion of factors affecting corrosion resistance of stainless steels. *Cooper Alloy Foundry*

1752. Cutting Oil
80 pages of factual data on more than 50 typical metalworking jobs in "Cutting and Grinding Facts". *Sun Oil*

1753. Cutting Oil System
Illustrated booklet gives data and charts on new cutting oil, dispensing jet and motor-driven pump. Contains test results of overhead flood with conventional coolants vs. new twin development. *Gulf Oil*

1749

This 28-page index lists the most commonly used copper alloys with the applicable specifications of nine different government agencies. The specifications are also given in numeric sequence for ease of reference. ***American Brass Co.***

1754. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *Du Pont*

1755. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

1756. Die Steel
Composition, properties and treatment of waterhardening alloy steel for cold heading dies, for life two to four times greater than formerly available. *Allegheny Ludlum Steel*

1757. Drawing Compounds
Folder describes new type of lubricant for cold forming and drawing of stainless steel, both austenitic and ferritic. *Hangsterfer's Laboratories*

1758. Drawing and Forming
Literature on Granodraw coating for improved drawing, cold extrusion and cold forming. *American Chemical Paint*

1759. Ductile Iron
New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. *International Nickel Co.*

1760. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

1761. Electrodes, Hard-Facing
Bulletin describes line of hard-facing alloy electrodes; typical applications, physical properties, welding procedure and identification. *Alloy Rods*

1762. Electromagnet
Bulletin on multipurpose high-flux-density electromagnet for metal research. *Arthur D. Little, Inc.*

1763. Electron Microscope
New 20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

1764. Electro-Polarizer
Bulletin on instrument for precise polarographic analysis in chemical determinations on very small samples. *Patwin Div.*

1765. Ferro-Alloys
64-page book describes over 50 metals and alloys produced by company. *Electro Metallurgical Co.*

1766. Finishes
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

1767. Finishes for Aluminum
8-page reprint on surface preparation, electrochemical, organic, ceramic, mechanical and chemical finishes for aluminum alloys. *Alcoa*

1768. Flaw Detection
Information on electronic equipment for nondestructive inspection of regular and irregular iron and steel parts. *Magnetic Analysis Corp. (Foerster)*

1769. Flow Meters
12-page catalog 40 on variable-area flow meters having tapered metering tubes and designed for high temperature and pressure. *Fischer & Porter Co.*

1770. Forging Manipulators
Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

1771. Forming Dies
Data sheet gives information on roller dies for forming tubes, pipe and cold rolled shapes. For all roll forming machines. *American Roller Die*

1772. Foundry Coatings
Brochure on foundry practices as related to colloidal graphite for mold washes, pattern coatings, core coatings, chill coatings. *Acheson Colloids*

1773. Foundry Compound
Data sheets on moldable exothermic feeding compound for nonferrous and ferrous castings. *Foundry Services, Inc.*

1774. Foundry Practice
Article on refining secondary copper alloys deals with sequence of removal of Al, Mn, Si, P, Fe, Zn, and use of pure oxygen instead of air. *R. Lavin & Sons*

1775. Foundry Wash
Bulletin on zirconite all-purpose paste wash for foundry applications. *Titanium Alloy Mfg.*

1776. Furnace Brazing
8-page article describes electric furnace brazing of ordnance assemblies at Southern Electro-Plating Co. *Sunbeam*

1777. Furnace Controls
28-page catalog 51-1 on furnace and oven controls lists prices and illustrates variety of instruments such as temperature controllers, recorders, indicators and valves. *Minneapolis-Honeywell*

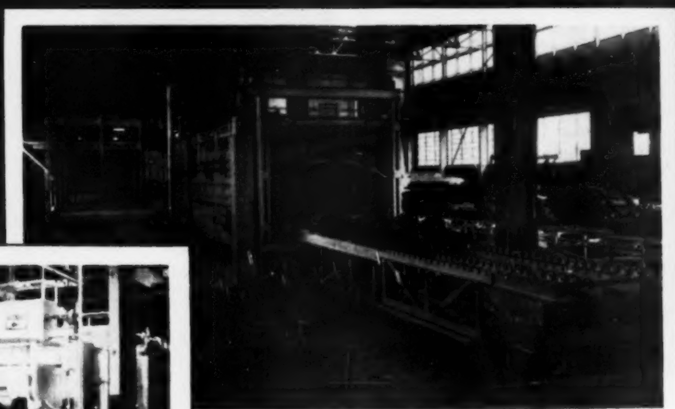
1778. Furnaces
High temperature furnaces for temperatures up to 2000 °F are described in leaflet. *Carl-Mayer Corp.*

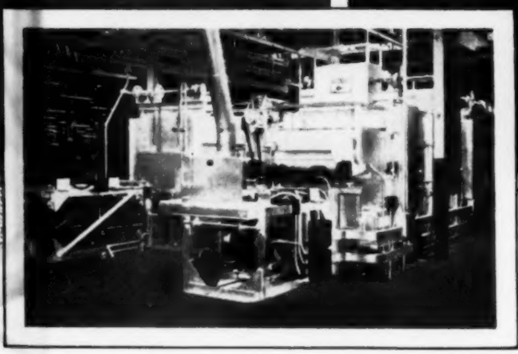
1779. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000 °F. *Harper Electric Furnace*

1780. Furnaces
Catalog on electric furnaces for tool room and general-purpose heat treating; also 600 °F. ovens. *Cooley Electric*

1781. Furnaces
40-page book describes gas and electric furnaces and applications. Four basic types of atmospheres. Glossary of heat treating terms. *Westinghouse*

1782. Furnaces
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*





1783. Furnaces
Bulletin B-90 on electric and fuel fired roller-hearth furnaces for heat treating. Atmosphere generators included. *Drever*

1784. Furnaces
Bulletin 1051 on furnaces for continuous brazing, sintering, annealing, forging, heat treating. *Harper Electric*

1785. Furnaces, Annealing
Folder of performance and cost data on radiant tube and roller hearth furnaces. *Gas Machinery*

1786. Gas Analysis
Theory of gas analysis, procedures in various analyses and maintenance and operation of equipment in 60-page manual. *Fisher Scientific*

1787. Gas Carburizing
Bulletin on gas carburizing in rotary furnaces. *American Gas Furnace*

1788. Gas Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1789. Grinding Samples
Bulletin on equipment for fine grinding of specimens with hand and motor powered grinders. *Buehler Ltd.*

1790. Hardness Numbers
Pocket-size table of Brinell hardness numbers, incorporating other tabular information of importance to the metallurgist, inspector and engineer. *Steel City Testing Machines, Inc.*

1791. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

1792. Hardness Tester
Bulletin ET 202 on new Ernst portable hardness tester for direct at-the-job readings of all metal types and shapes. *Newage International*

1793. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, copper, brass, bronze, plastics. *Barber-Colman*

1794. Hardness Tester
Bulletin on Rockwell-type instrument having optical system to give Rockwell readings directly on a dial. *Opplem Co.*

1795. Heat-Resistant Gloves
Bulletin on heat-resistant gloves for heat treating and welding operators. *C. Walker Jones*

1796. Heat-Resisting Alloy
"Hastelloy Alloy X" describes new Fe-Ni-Cr-Mo alloy, properties and forming characteristics. *Haynes Stellite*

1797. Heat-Resisting Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion to 2000° F. *Chicago Steel Foundry*

1798. Heat Treat Furnace
Bulletin 341 on convection furnace for hardening and tempering. *Hevi Duty*

1799. Heat Treating
Catalog 116 contains 72 pages of heat treating data for carburizing, cyaniding, brazing, austempering and annealing processes. *Ajax Electric*

1800. Heat Treating
12-page bulletin on heat treating in a steam atmosphere. *Leeds & Northrup*

1801. Heat Treating Aluminum
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1802. Heat Treating Fixtures
Extensive catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1803. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

1804. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div*

1805. Heating Equipment
12-page bulletin on blowers and high-temperature fans. *General Blower Co.*

1806. Heating Equipment
Bulletin, "Make Your Own Gas", describes generator to convert oil to gas for standby or primary fuel. *Vapofier*

1807. Heliarc Welding
Pocket-sized folder contains current ranges and sizes for electrodes with table on current and number of passes required to weld various metals. *Linde Air Products*

1808. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

1809. High-Temperature Alloys
High temperature work sheet provides valuable suggestions for solving high temperature problems in design and production. *International Nickel*

1810. Immersion Heating
Bulletin 1E-11 gives complete details on how immersion pots save time in melting soft metals. *C. M. Kemp Mfg.*

1811. Impregnation of Castings
Literature on new impregnating equipment for elimination of porosity in ferrous and nonferrous castings. *Metallizing Co. of America*

1812. Induction Heating
Bulletin 1440 on system for safety control of induction heating through use of components built into every unit. *Lindberg Engineering*

1813. Induction Heating
Catalog MP-12 describes portable high frequency induction heating unit for brazing, hardening, soldering, anealing and melting. *Lepel High Frequency*

1814. Induction Heating
12-page bulletin on equipment for induction heating. Requirements for hardening, brazing, and annealing at 1000, 3000, and 10,000 cycles. *General Electric*

1815. Induction Heating
Bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forging, extrusion and rolling. *Loftus Eng'g*

1816. Induction Heating
"Induction Heating" . . . presents case histories of increased production, reduced space, lower costs. *Westinghouse*

1817. Industrial Photography
Book entitled "Functional Photography in Industry" describes processes and techniques. *Eastman Kodak*

1818. Industrial Planning
Book 127 on planning expansion, remodeling or modernization of plant. *Continental Industrial Engineers*

1819. Industry Expansion
Booklet deals with the growth of industry in Kalamazoo, Mich., over a period of 70 years. *Hammond Machinery*

1820. Inert Gas Welding
Heliwelding, inert-gas-shielded arc-welding process for all-position welding of aluminum, magnesium, stainless steel, brass and copper, in ADC-709, Catalog 9. *Air Reduction*

1821. Inspection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

1822. Instruments
"Tomorrow Is Today" is a new brochure telling of the many contributions of instruments to industrial processing. *Minneapolis-Honeywell*

1823. Ion Exchange
24-page discussion of ion exchange resins and applications. *Rohm & Haas*

1824. Iron-Nickel Alloys
32-page bulletin on austenitic iron-nickel alloys having special thermal expansion or thermoelastic characteristics. *International Nickel*

1825. Laboratory Furnaces
Series of data sheets give full information on complete line of laboratory furnaces for numerous metallurgical operations. *Boder Scientific*

1826. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

1827. Liquid Carburizing
Data folder on Aerocarb A and B compounds for salt-bath carburizing. Case depth vs. time, %C and %N penetration curves. *American Cyanamid*

1828. Lockseam Tubing
Blueprint of size ranges of round or oval lockseam tubing in a wide range of metals. *H & H Tube and Mfg.*

1829. Low-Hydrogen Electrodes
Comparison chart of brand names of 16 manufacturers of low-hydrogen electrodes. *Arcos*

1830. Lubricant
40-page booklet on moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1831. Magnesium Welding
Reprint describes an investigation to evaluate inert-gas-shielded metal-arc welding of magnesium. *Air Reduction*

1832. Magnetic Alloys
8-page booklet 52-100 gives properties and uses of Hipernik, Conpernik, Hiperco. *Westinghouse*

1833. Malleable Iron
Metallurgy, treatment, and heat treated properties of malleable iron are described in Reprint 51-B. *Surface Combustion Corp.*

1834. Mechanical Cleaning
76-page catalog 210 simplifies selection of power brushes; various types of brushes in operation. *Osborn Mfg.*

1835. Melting Furnaces
24-page book on electric furnaces for steel mills and foundries. Many photographs of furnaces in action. Table of types, sizes, ratings. *American Bridge*

1836. Metal Analysis
Brochure on Quantometer, which furnishes pen-and-ink records of quantitative spectrochemical analyses with extra copies. *Applied Research Labs.*

1837. Metal Saws
Folder on new band saw of 24 by 24 in. capacity. *W. F. Wells & Sons*

1838. Metallograph
Revision of catalog includes the new metallograph with polarizing and phase attachments. *American Optical*

1839. Micrographic Equipment
6-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000 ×. Full details on optics and accessories included. *Opplem Co.*

1840. Microhardness Tester
Bulletin DH-114 on Tukon hardness testers in research and industrial testing. *Wilson Mechanical Instrument*

1841. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Kent Cliff Laboratories*

1842. Microscope
Catalog about heating microscope, equipped with Leica camera, designed for studying melting behavior. *E. Leitz*

1843. Nonferrous Melting
12-page bulletin on eight types of gas furnaces for melting nonferrous metals. *Bellevue Industrial Furnace*

1844. Nonferrous Melting
Bulletin 50-A on crucible furnaces for nonferrous metals. *Mahr Mfg.*

1845. Nonferrous Metals
"Metal of the Month" letters include market trends and helpful data. *Belmont Smelting & Refining*

1846. Nonferrous Tubing
Bulletin on seamless, brazed and lockseam tubing in brass and copper. *H & H Tube and Mfg.*

1847. Oil Quenching
Catalog V-1146 on self-contained oil cooling equipment. Detailed solutions to typical problems. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

1848. Optical Pyrometer
New Catalog 85 on self-contained, direct reading optical pyrometer. Specifications, operating procedures. *Pyrometer Instrument Co.*

1849. Periodic Chart
Latest periodic chart of the elements. Green and black, 11 by 14 in., official 1952 data. *General Electric*

1850. Pickling Baskets
Information on baskets for degreasing, pickling, anodizing and plating. *C. O. Jelliff*

1851. Pit Furnace
Bulletin 451 on pit furnace 156 in. deep for heat treating. *Hevi Duty*

1852. Plating
Bulletin CR-110-5 describes equipment, bath, operating conditions and control of high-speed chromium plating process. *United Chromium*

1853. Polishing Materials
20-page booklet includes samples of emery, aluminum oxide and silicon carbide papers and 12 polishing cloths. *Buehler Ltd.*

1854. Portable Potentiometer
Bulletin A502 discusses lightweight portable potentiometer accurate to 0.025 mv. *Wheelco*

1855. Pot Furnaces
Bulletin D-50 on gas-fired pot furnaces for hardening and tempering in lead or molten salt. *Eclipse*

1856. Potentiometers
Article in Rubicon Notes gives technical data on semi-precision potentiometers. *Rubicon*

1857. Powder Metallurgy
Data sheet on zinc stearate as a lubricant in powder metallurgy. *American Cyanamid*

1858. Powder Metallurgy
Folder on applications of powder metallurgy to mass-production parts. *American Sintered Alloys Div.*

1859. Precision Grinding
8-page article on oils for precision grinding, from Notebook. *D. A. Stuart*

1860. Pre-Plated Metals
16-page fabrication handbook on pre-plated metals, ferrous and nonferrous. *American Nickeloid*

1861. Protective Coating
Reprint on zinc-containing protective coating applied like paint. *Industrial Metal Protectives*

1862. Punching and Shearing
Bulletin on machine that combines in one unit a punch, bar and shape cutter, coper and plate shear. *Maddaus Moelders*

1863. Purification of Plating Solutions
Bulletin 26 on purification of nickel plating solutions with hydrogen peroxide. *Buffalo Electro-Chemical*

1864. Pyrometers
12-page Bulletin 713 on indicating and controlling pyrometers. Functional diagrams of installations. *General Electric*

1865. Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1866. Quenching
8-page bulletin on continuous quench tank conveyor. *Klaas Machine & Mfg.*

1867. Refractories
20-page booklet gives technical information on super refractories. Charts, tables and application data. *Refractories Div., Carborundum Co.*

1868. Refractory
12-page brochure on new magnesite-chrome refractory, electrically melted and cast, for steel melting. *Corhart Refractories*

1869. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

1870. Refractory Mixes
16-page bulletin No. 315 on properties and applications of sillimanite super-refractory ramming mixes and furnace patches. *Chas. Taylor Sons*

1871. Rhodium Plating
Directions for rhodium plating, with reference to use as replacement for usual plating metals. *Baker & Co.*

1872. Rust Proofing
Literature on Permadine for rust-proofing ferrous metal parts. *American Chemical Paint*

1873. Salt Bath Control
Data sheet 5.2-5 describes instrumentation for temperature control of salt baths in heat treatment of high speed steel. *Minneapolis-Honeywell*

1874. Salt Bath Furnaces
Illustrated folders give data on salt bath furnaces for batch and conveyorized work. *Upton Electric Furnace*

1875. Salt Baths
32-page bulletin, "Liquid Salt Baths", discusses heat treating salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton & Co.*

1876. Sand Control
See review on page 27. *Claud S. Gordon*

1877. Saws
Catalog 49 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1878. Seamless Tubing
52-page "Handbook of Seamless Steel Tubing". Production and properties. 26 pages of data. *Timken*

1879. Shears, Metal C
16-page catalog on pi shears for cutting metal up thick. *Cleveland Crane & I*

1880. Silver Brazing
48-page manual on all as ver brazing applications an *American Platinum Works.*

1881. Soldering Alum
Article on techniques an for soldering aluminum. *Metals*

1882. Solvent Cleanin
24-page brochure on cleaner to follow solvent de other precleaner. *Northwes*

1883. Spring Steel
Handbook describes var steels and gives tolerance treatment and physical prop and fabrication data. *A. R*

1884. Spring Wire
Data on oil tempered spr help solve coiling, knottin and twisting problems. *Pitts*

1885. Springs
Information on compress flat, extension and special sp *Evans Sons, Inc.*

1886. Stabilized Stain
Bulletin 144 on Type 3 tubing. Condensed data o and fabrication. *Babcock &*

1887. Stainless, Type
12-page book on fabricat of Type 430 stainless ste *Steel*

1888. Stainless Fabri
133-page book covers we ing, soldering, joint design, forming, annealing, picklin of stainless steels. *U. S. St*

1889. Stainless Steel
44-page book gives detail tion on use of stainless s chemical industries. *Cruci*

1890. Stainless Steel
Slide chart. Set top at a ricating operation, bottom s of each standard grade. side, heat treating and co are given. *Carpenter Steel*

1891. Stainless Steel
32-page book on corrosio of stainless steels. 18 tab in acid, neutral and alkali *International Nickel*

1892. Stainless Steel
12-page book, "Type 4 Steels as Alternates of the Fabrication data, four pag

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parative corrosion ratings for Types 430, 302 and 316. *Republic Steel*

1893. Steel, Low-Alloy
Booklet on Hi-Steel, with nearly twice the working strength of ordinary steels plus impact resistance. *Inland Steel*

1894. Steel, Low-Alloy
8-page folder on N-A-X low-alloy, high-strength steels lists properties and test specifications. *Great Lakes Steel*

1895. Stereomicroscopes
20-page brochure on microscopes for three-dimensional magnification up to 45 diameters. *Bausch & Lomb*

1896. Straightening Tube
8-page Bulletin 52 on experience at seven plants with rotary straighteners for tubular products. *Mackintosh-Hemphill*

1897. Straightening Wire
Bulletin 52-AA describes straightening machine for wire in size range from 1/16 to 1 in. diameter, at speeds up to 200 ft. per min. *Medart Co.*

1898. Subzero Freezer
8-page folder on portable freezer, 110-volt a.c., operating to −180°F., for shrink fitting, hardening, stabilizing and testing. *Webber Appliance*

1899. Subzero Treatment
Advantages of low-temperature metal treatment are described in a new 8-page folder. Processes covered are for stabilization, increasing tool life and shrink-fit assembly. *Sub-Zero Products*

1900. Super High Speed Steel
Folder on molybdenum, 8% cobalt high speed steel for use at speeds 20 to 25% greater than with ordinary high speed steel. Heat treatments, protective coatings and uses. *Firth Sterling*

1901. Tank Linings
12-page bulletin 526 on thermoplastic lining material. Tabular data on chemical resistance. *U. S. Stoneware*

1902. Tempilstiks®
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

1903. Testing
Bulletin on mechanical and nondestructive testing and on certification in accordance with procedure set up by the American Standards Association. *American Standards Testing Bureau*

1904. Testing Equipment
New 80-page illustrated catalog lists over 130 testing and measuring equipments for laboratory and production line use. *General Electric*

1905. Testing Machines
Bulletin 44 describes hydraulic universal testing machines in capacities from 60,000 to 400,000 lb. *Tinius Olsen*

1906. Textured Stainless
6-page folder on suggested uses for stainless metals to conserve strategic alloys and reduce weight. *Rigidized*

1907. Thermocouples
20-page bulletin 714 on thermocouples, protecting tubes and wells, insulators, leads, connectors, heads. *General Electric*

1908. Thermocouples and Pyrometer Accessories
56-page book comprising a User's Manual, illustrated Buyers' Guide with specifications and prices and thermocouple calibration data. *Bristol Co.*

1909. Tin
20-page book on production, consumption and uses of tin. *Malayan Tin Bureau*

1910. Tool Steel Color Guide
Color guide to estimate the temperatures of heated steels has heat colors on one side and temper colors on the other side. *Bethlehem Steel*

1911. Tool Steel Selector
Selector is handy chart featuring general and heat treating data on nondeforming, water hardening, shock-resistant, hot work, high speed tool and hollow die steels. *A. Milne & Co.*

1912. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

1913. Tool Steels
Stock list of available tool and die steels. *Reliable Steel*

1914. Transition Manufacturing
16-page brochure on service which bridges gap between development engineering and commercial production. *Cambridge Corp.*

1915. Tubing Failures
Factors affecting tube life in high-pressure, high-temperature applications are presented in 40-page booklet, the result of a great number of investigations of failures. *Babcock & Wilcox*

1916. Tumbling Barrels
10-page catalog B-8 gives specifications, applications of six types of tumbling barrels. *Globe Stamping Div.*

1917. Tungsten Electrodes
Wall chart gives data for inert-gas arc-welding of aluminum, magnesium, stainless steel with pure and thoriated tungsten electrodes. *Sylvania*

1918. Vacuum Metallizing
Folder on tungsten filaments for use in vacuum metalizing. Both flat sheet and formed wire heaters. *Sylvania*

1919. Vacuum Metallurgy
Bulletin gives resume of vacuum metallurgical operations and research and development facilities and services available. *National Research Corp.*

1920. Vapor Degreaser
Vapor degreaser described and diagramed in folder. Data on different models. *Topper Equipment*

1921. Water Softener
16-page bulletin 2386 explains three basic types of ion-exchange equipment. *Permutit Co.*

1922. Welding Equipment
Cadweld process and complete list of arc-welding accessories are described in catalog. *Erico Products, Inc.*

1923. Welding Low-Alloy Steel
12-page booklet guides users of low-alloy, low-hydrogen electrodes. *Arcos Corp.*

1924. Welding Mild Steel
48-page manual on welding of mild steel with mild steel, low alloy and special-purpose electrodes. Also hard facing. *McKay Co.*

1925. Welding Nickel Alloys
New 44-page book on fusion welding of nickel and high-nickel alloys. Illustrated and containing more than 30 tables. *International Nickel*

1926. Weld-Rod Stabilizer
4-page bulletin on low-hydrogen electrode stabilizer. Includes complete specifications of company's equipment for dehydrating mineral shielding on low-hydrogen electrodes. *Fred C. Archer*

1927. X-Ray Equipment
"Industrial X-Ray Accessories", on equipment, chemicals, dark-room accessories, filing equipment, tanks, dryers and instruments. *Picker X-Ray*

1928. X-Ray Inspection
Bulletin 400-520 on jib-crane unit for applications where horizontal and vertical travels of standard tubestand are inadequate. *Westinghouse*

1929. X-Ray, Portable
Specifications for lightweight, portable 260 kvp. industrial X-ray machine. *Triplett & Barton*

1930. Zirconium
Mechanical and corrosion properties of pure ductile zirconium; also new price schedule. *Foote Mineral*

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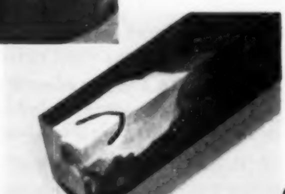

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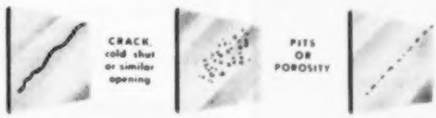

CRACK, cold shut or similar opening

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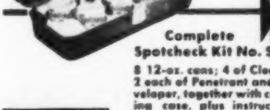

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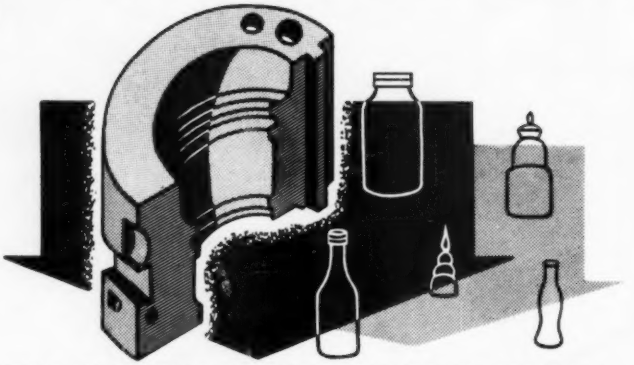

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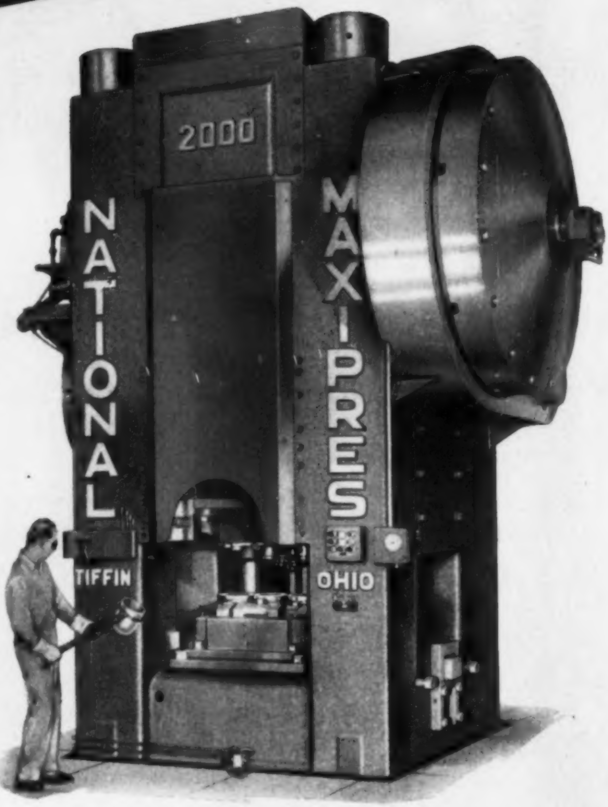

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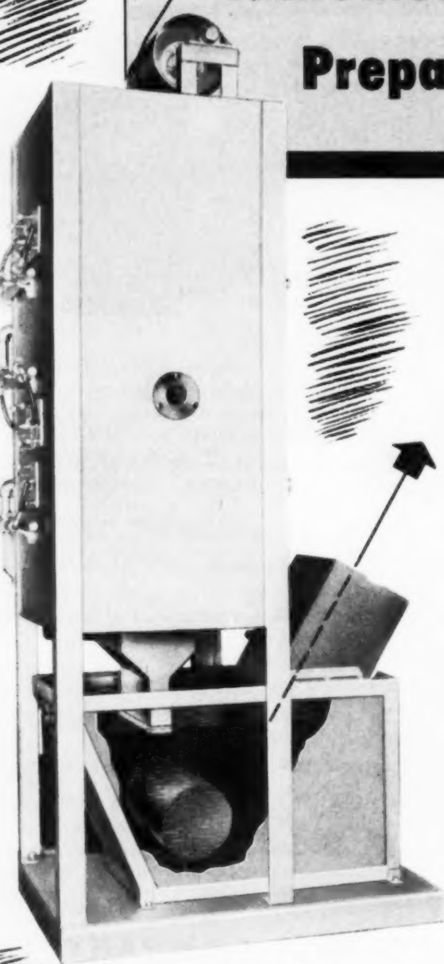

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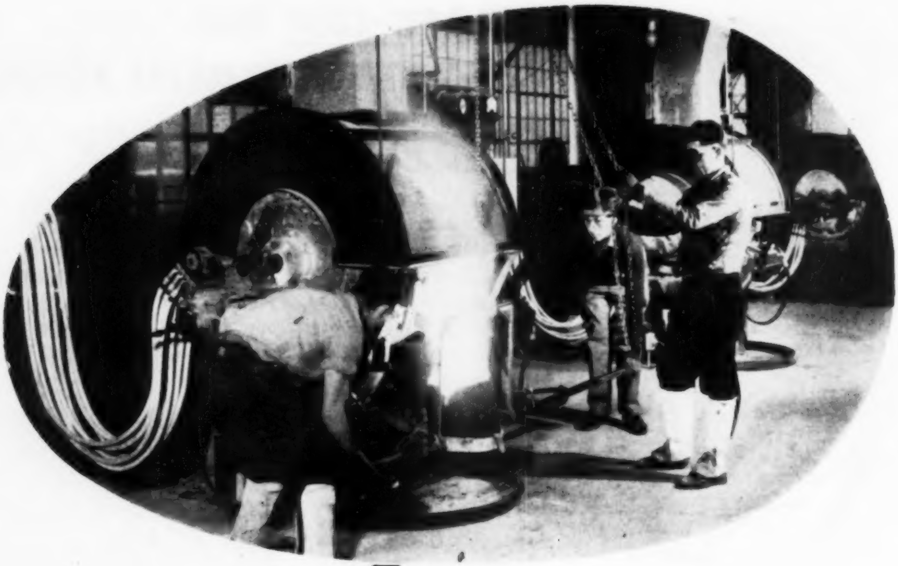

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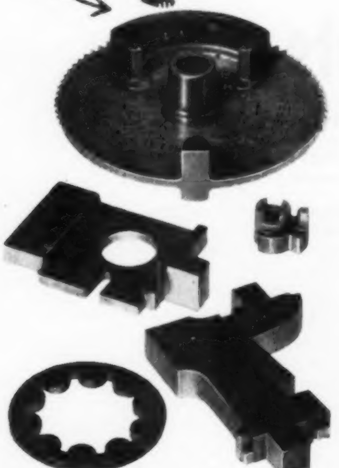

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Above you see the Crown and Bed of an 800 Ton Press produced by Steel-Weld Fabrication in the Mahon plant for one of the largest manufacturers of heavy presses. These massive pieces, and the parts and assemblies illustrated at the left, are typical of thousands of units Steel-Weld Fabricated and machined by the Mahon Company for manufacturers throughout the country. If there are parts or assemblies in your product that could be redesigned and produced in welded steel to better advantage from a strength-weight standpoint, or, if you are faced with a limited production on an item involving heavy pieces in which pattern costs are a consideration, you can turn to Mahon with confidence. You will find in the Mahon organization a unique source with complete, modern fabricating, machining and handling equipment to meet your requirements . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job, embodying every advantage of Steel-Weld Fabrication. See Mahon's Insert in Sweet's Product Design File, or have a Mahon Sales Engineer call on you at your convenience.
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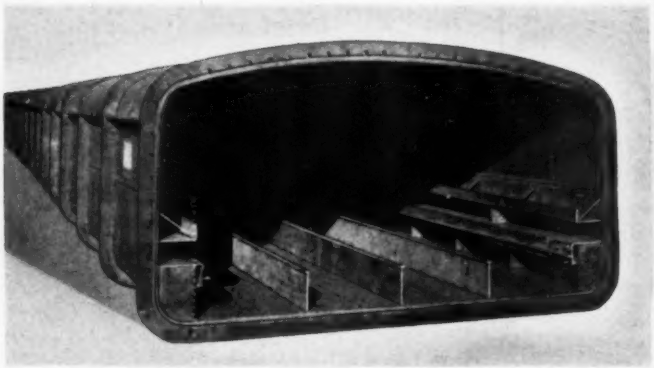
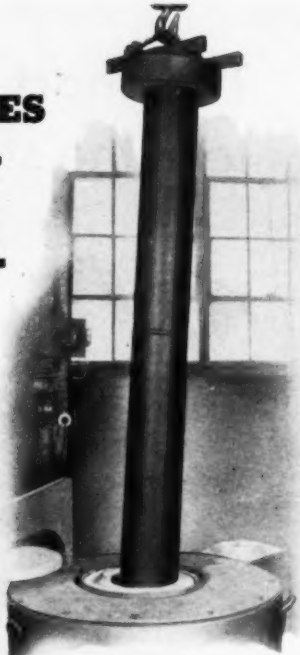
PSC L-O-N-G WEARING MUFFLES

for LONG WORK





Above, retort for gas carburizing long shafts; suspended to prevent distortion.

Left above, muffle for annealing brass, copper; 40 ft. long; two sections bolted together. Fabricated in any length.

The above muffle and retort, for heat-treating long work, are examples of how PSC designed-for-the-job units are helping customers meet special production problems. Substantial economies in handling and heating time as well as in fuel are reported.

Fabricated from the particular sheet alloy which will best withstand your specific temperatures, PSC muffles and retorts have wearing records as much as 20 times that of former units. For the solution of such problems as embrittlement, atmosphere leakage and costly maintenance, we invite you to take advantage of our wealth of experience in fabricating a complete line of heat-treating equipment. We specialize in muffles and retorts for special situations where design becomes a prime factor.

Heat-Treating Equipment for Any Product and Any Metal

Carburizing and Annealing Boxes	Tumbling Barrels · Tanks
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A complete standard reference on equipment for every purpose.

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Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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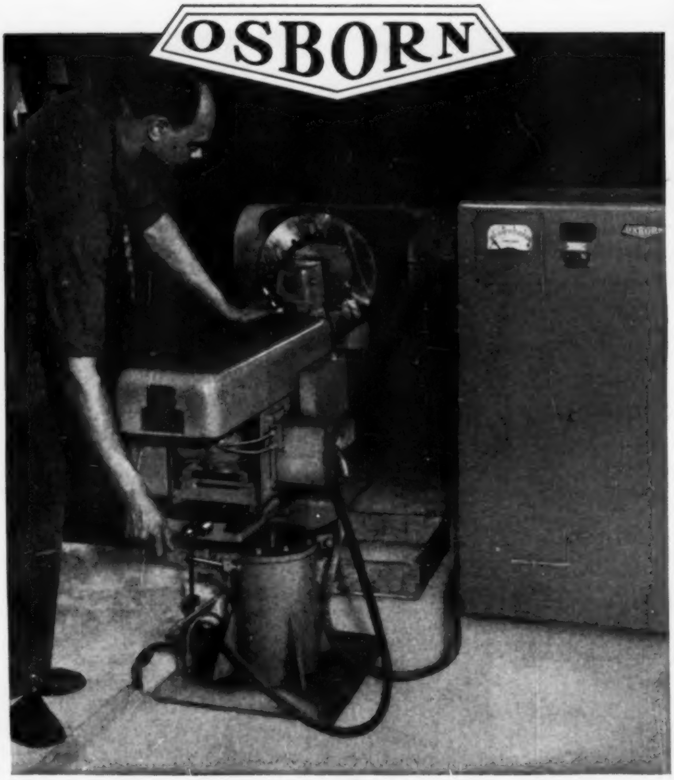


Deburrs gears 15 times faster at the push of a button!

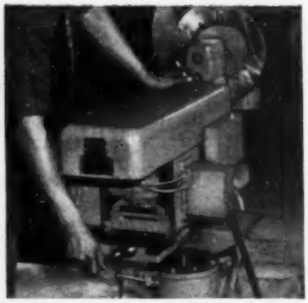
Want to break a big bottleneck in the production of gears and similar parts? Manufacturers are doing just that with the Osborn Work Holder Brushing Lathe.

In the plant of the White Motor Company, Truck Division, Cleveland, Ohio, this Osborn machine deburrs and finishes gear teeth 1570% faster than the old method. This was done formerly with a portable grinder . . . a tedious operation that took 25 minutes for the 14-inch hypoid gears shown. Now, an operator simply places the gear in the Osborn Work Holder Brushing Lathe, pushes a button and the machine does the job automatically. Floor-to-floor time is only 1½ minutes! Uniformity of finish results in additional time savings in matching and assembly of gears.

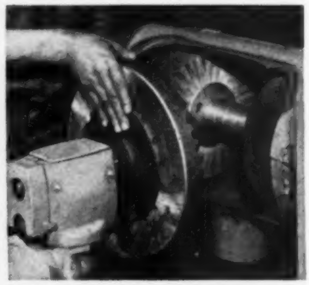
It will pay you to investigate this high-speed, high-quality machine for deburring and finishing gears on a production basis. Call your **O**sborn **B**rushing **A**nalyst today or write *The Osborn Manufacturing Company, Dept. 895, 5401 Hamilton Avenue, Cleveland 14, Ohio.*

Osborn Brushes

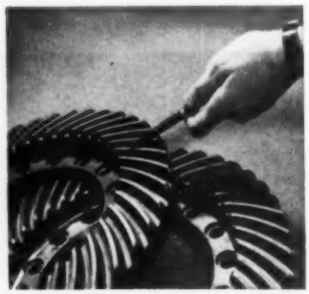
OSBORN POWER, MAINTENANCE AND PAINT BRUSHES AND FOUNDRY MOLDING MACHINES



SET-UP IS SIMPLE. The machine is versatile. If your production involves small runs of many different types and sizes of gears and similar parts, you can specify machine settings for each part and operator can make set-up changes easily and quickly for maximum daily output. The complete brushing cycle is controlled automatically by the electronic timer which is set for any desired brushing interval to suit the size, shape or condition of part being brushed.



OPERATION IS SPEEDY. The operator mounts the gear easily and quickly. The gear advances to the face of two rotating Osborn brushes and the edge of the gear teeth makes contact with the brushes. To assure fast, positive action on each piece brushed, an automatic control reverses the direction of brush rotation on every cycle of operation.



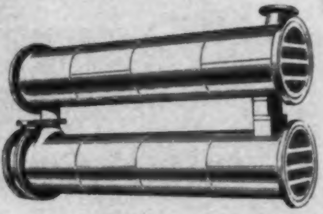
RESULTS ARE UNIFORM. Burrs and sharp edges are removed uniformly. Every gear tooth has smooth, uniform rounded edges. Surfaces are blended.

INVESTIGATE IT TODAY

for *your* problems. Users report time savings ranging from 20% to 1570% with the Osborn Work Holder Brushing Lathe. Let us demonstrate what it can do for you!

HAYNES Alloy Tubing
Trade-Mark

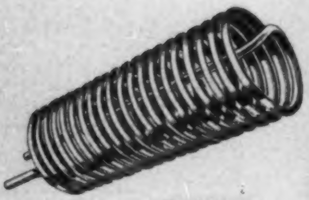
FOR SEVERE SERVICE CONDITIONS



Heat Exchangers

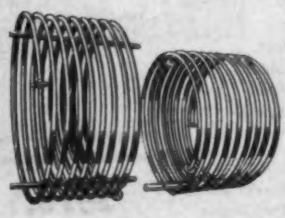
Tubing made of HAYNES alloys gives long, uninterrupted service under severe conditions of heat, corrosion, or oxidation. The tubing can be obtained in four different alloys, each having a particular combination of unusual properties to combat certain service conditions. The chart below shows some of the media these alloys resist. Typical applications are heat exchangers, coils, calandrias, and fluid lines.

All four HAYNES alloys are supplied in welded or welded and cold drawn tubing. Most common welding methods—including metallic-arc and HELIARC welding—can be used in fabricating the tubing installations. If you wish further information about HAYNES alloy tubing, contact the nearest Haynes Stellite Company district office.



Fluid Lines

USE TUBING OF	FOR RESISTANCE TO
HASTELLOY Alloy B (nickel-molybdenum-iron)	Hydrochloric acid, wet hydrogen chloride gas, sulphuric acid, phosphoric acid, organic acids, high temperatures.
HASTELLOY Alloy C (nickel-molybdenum-chromium-iron)	Nitric acid, free chlorine, acid salts, hydrochloric acid, sulphuric acid, phosphoric acid, organic acids, sulphurous acid, high temperatures.
MULTIMET Alloy (cobalt-chromium-nickel-iron)	Oxidation, high temperatures.
HAYNES Alloy No. 25 (cobalt-chromium-tungsten-nickel)	Oxidation, high temperatures, carburization, wet chlorine, nitric acid.



Coils

HAYNES *alloys*
TRADE-MARK

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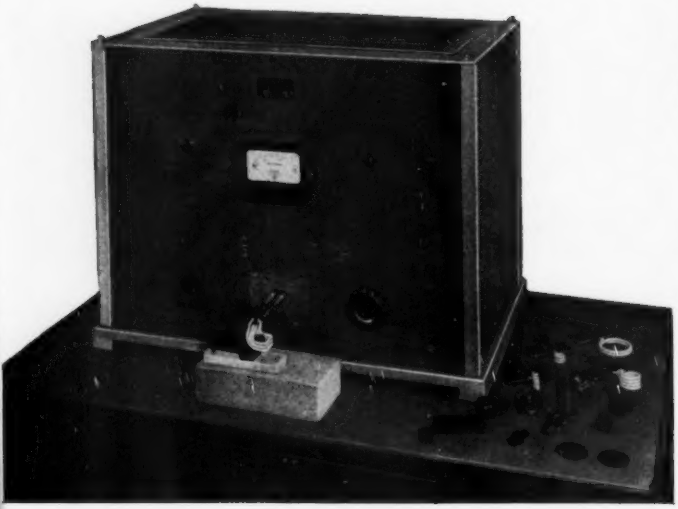
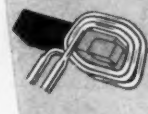
Lepel *presents*

A *Low Cost* PORTABLE HIGH FREQUENCY *Induction* HEATING UNIT

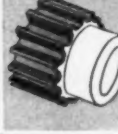


BRAZING



Permits widest choice of silver or copper brazing alloys from lowest to highest melting points. Ideal for brazing carbide tips.

HARDENING



Heat localized exactly where wanted at desired temperature. Ideal for gears, cams, bearing surfaces, cutting tools and other areas that are subject to wear.

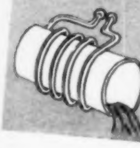
SOLDERING

Speedily and neatly performs intricate soldering applications with or without the use of pre-formed rings.

ANNEALING

Ideal for annealing, stress-relieving, normalizing or pre-heating selected areas.

MELTING



Readily melts quantities of ferrous and non-ferrous metals in either graphite or ceramic crucibles.

- **SMALL AND COMPACT**
  Conveniently operated on bench or table—no mounting necessary.
- **ECONOMICAL OPERATION**
  No special power installation required. Operates on 110 volts, 60 or 50 cycle line at unity power factor.
- **FULLY GUARANTEED**
  Guaranteed for continuous duty cycle and stated performance.

This versatile unit is priced so low that every shop may now take advantage of modern induction heating techniques to improve quality and to increase production. Its simplicity of operation eliminates the need for skilled personnel.

The Lepel Model 2 KW will meet the requirements of machine shops, toolrooms, research laboratories and educational institutions. It is especially suitable for hardening, brazing and soldering small parts of either ferrous or non-ferrous metals.

Complete unit with line connection and load coil.

$870.
f.o.b. factory

WILL HEAT TO 1500° F.

1/8"	steel rod 1" length in approx.	1 second
1/4"	" " " " " "	3 seconds
1/2"	" " " " " "	15 seconds
1"	" " " " " "	60 seconds

Will melt 4 ounces of brass or steel in 4 minutes.
Equally well suited for heating of non-ferrous metals.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

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that will LAST...
Think of
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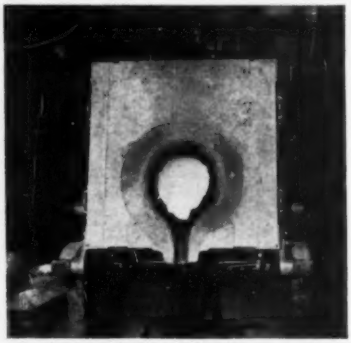
First
WHEREVER quality and long life count, you'll find American industry using H & H brass and copper tubing and fabricated parts. The H & H LOCKSEAM tubing in the jeep radiator at the left is widely used in automotive heating and cooling components, while the fabricated parts shown in the same illustration are typical of other H & H applications. If *your* operation calls for tubing that will *last*, call your nearest H & H representative *first*.
LOCKSEAM TUBING*
Available in round or oval shapes, in a wide range of metals. Precision cut to random or specified lengths in sizes to meet requirements of heating and cooling field. Solder coated on outside or both sides.
*Blueprint of size ranges and standard tubes furnished upon request.
H&H TUBE AND MANUFACTURING COMPANY
METALFLO
LOCKSEAM
COIL STRIP
AND
SEAMLESS TUBING
TUBULAR PARTS

RAMMING Norton MAGNORITE cement lining into an Ajax 300-lb. high frequency induction furnace. This cement has been developed specifically to be dry rammed and will withstand temperatures up to 3250 F. It provides densest possible lining for resistance to metal penetration and erosion.

MOLTEN STEEL is here poured into ladles. Due to the employment of fractional tapping, cement lining must withstand much longer periods of holding melt at pouring temperatures. Highly refractory Norton MAGNORITE cement insures long life and low maintenance cost even under these conditions.



MAGNORITE CEMENT LINING shows no evidence of erosion or chemical attack after metal has been completely poured, thus assuring minimum repairs. This cement is designed to have a slight expansion upon maturing to eliminate shrinkage cracks which might lead to furnace failure.

Melt more metal per lining

with Norton Refractory cements

You'll get long life, low maintenance cost from your furnace linings by using Norton refractory cements. *You'll melt more metal per lining.*

These cements are available in a variety of refractory compositions designed to meet your individual needs. *Norton MAGNORITE* cement*, for instance, is used in high frequency furnaces for a wide variety of melts, ranging from straight steels to heat-resistant compositions. *Norton FUSED STABILIZED ZIRCONIA* crucibles are excellent for melting platinum and its alloys. This sensational refractory is not wetted by the metal, permitting 100% recovery of the melt without destroying the crucible. *Norton ALUNDUM* and MAGNORITE* crocks, covers, and cements are used successfully in indirect arc furnaces. These cements are also used in low frequency furnaces for melting such refractory alloys as cupro-nickel and nickel silver; high copper alloys and Al, Te, and Si bronzes. *ALUNDUM* cement is also excellent for handling stainless steel.

For heat-treating and sintering furnaces investigate ALUNDUM and CRYSTOLON* hearth plates, pier brick, burner blocks, muffles, muffle plates, skid rails, recuperator tubes, burner-tunnel, and embedding cements.

Whatever your problem, you can depend on satisfactory solution when Norton research engineers Norton refractories to fit your exact requirements. For further information, see your nearby Norton representative — or write direct to NORTON COMPANY, 331 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

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Metal Progress

Vol. 62, No. 6 · December 1952

The Atomic Age

Engineering Articles

Critical Points

Departments

Correspondence

Digests of Important Articles

Metal Progress

Critical Points BY THE EDITORS

The Annual Meeting and Exposition

THE 34th National Metal Congress and Exposition will be remembered as the largest, most colorful and best attended of all the long series. At Commercial Museum, adjoining the University of Pennsylvania's campus, 426 exhibitors filled all available space. Never was there such success in appealing to the eye of the passer-by. The Editor thought that the exhibits of the Dow Chemical Co.'s Magnesium Dept., Titanium Metals Corp. of America, Udylite Corp., and Edwin B. Stimpson Co., Inc., were exceptionally handsome among literally dozens of other fine ones. The management contributed to this aesthetic ensemble by rolling out two miles of royal-red carpeting a-down the aisles; its foam rubber backing gratefully yielded to tired feet. First steps were also taken toward a general decoration by the use of bright and colored metal. This is a difficult task for two reasons: Exhibit halls are either tremendous arenas or are cluttered with columns and roof trusses; either type of structure defies adornment except on a grand scale. Again, every exhibitor may be counted on to do his best to keep the eyes of the viewer *level* toward the booths rather than *up* toward the roof. Despite such competition, one may predict ultimate success, having in mind the many triumphs of the Society's management in its past history.

Much emphasis was laid on the educational activities of the in the reports of the national officers. With the assistance of the National Science Teachers Association, 38 awards were made to high-school students, their teachers and the schools' science departments for superior projects during the school year. Three young members of metallurgical faculties, Arthur A. Burr of Rensselaer, Joseph W. Spretnak of Ohio State, and Robert D. Stout of Lehigh, were given purses of $2000 and citations as outstanding teachers. The American Society for Metals' Foundation for Education and Research was approved by unanimous vote at the annual meeting, and securities valued at $650,000 were formally transferred from the treasury to that of the Foundation, the income of which is to be devoted to such metallurgical, educational and research projects as determined by its directors (the president and the four immediate past presidents of the Society). Finally, some 2000 engineering students at various colleges and universities within a 150-mile radius of Philadelphia were brought to the Exposition as the Society's guests on the last day.

Acta Metallurgica

IN HARMONY with this educational note was the announcement that the first issue of an international journal of metal science, dubbed *Acta Metallurgica*, would appear next January. Bruce Chalmers, professor of metallurgical engineering at University of Toronto, is editor. Preparatory work started about two years ago when Ray T. Bayless, assistant secretary, , was assigned by the Society's Board of Trustees to study such a publication — admittedly quite desirable in view of the steady increase in the research into the solid state and the scattered outlets now available for publication. The Board appropriated $50,000 to cover developmental expenses and a major fraction of the anticipated deficit for the first year of publication, and Cyril S. Smith, head of the Institute for the Study of Metals, became chairman of an Interim Board of Governors to guide the journal's first steps.

As of today the American Society for Metals is the only sponsor of *Acta Metallurgica* in the sense of making a financial contribution toward defraying its expense, and in return any member of the Society will receive a 50% reduction in subscription price. Fifteen other societies in America and abroad are cooperating by campaigning for subscriptions, and a "Board of Governors" has appointed associate editors in the various countries. In accordance with the original plan, *Acta Metallurgica* will confine its pages to discussions of the structure and properties

Critical Points

of metals in terms of the fundamental particles, forces and energies. In this editorial field it will be unique and there is little limit to the influence it will play in developing a scientific and mathematical basis for the more "practical" aspects of metallurgy.

Nonferrous Exhibits

This consulting editor would comment on the Exposition as it applies to his primary interest — nonferrous metals and articles produced therefrom. Individual comparison is a thing to beware; nevertheless one cannot resist mentioning some examples of the many worthwhile processes or products that impressed this visitor.

We have become accustomed to the beautiful and spectacular exhibits of the large brass, nickel and other nonferrous metal producers and exhibitors of foundry equipment. We salute them and continue on our round.

Today, a great effort is directed toward increasing purity in the metal or alloy. A generation ago not much was heard of gases and oxides in metal. Now the ultimate was seen in a display of furnaces by National Research Corp. for melting and casting *in vacuo*, whereby practically all dissolved gases can be eliminated, together with many of the volatile metallic impurities. Largest of these furnaces can now handle a charge of 1200 lb.; an alternative is to melt *in vacuo* and cast with a completely surrounding atmosphere of argon or helium.

(In passing it might be said that this development is one of the industrial dividends of the atomic energy program. High-vacuum techniques were applied on a grand scale in the electromagnetic devices for separating the explosive uranium isotope from the more stable metal.)

As we wandered on we found evidence that the magnesium castings had grown to giant size — witness a casting in Rolle Mfg. Co.'s exhibit weighing 1630 lb. Progress was noted on the magnesium-zirconium-zinc-thorium alloy, an improved material for aircraft parts in proximity to jet engines and therefore heated dangerously. (Mention of jets calls to mind the interesting cut-away exhibit of such an engine in the booth of Crucible Steel Co. of America, which the onlooker might start by simply throwing a switch. We can now say that we drove a jet engine even if we did not fly it!)

1952 would seem to be the year of titanium, judging by the attention given in technical discussions and in the Exposition itself, where many forms ranging from 2-ton ingots to small forgings, fine wire and thin sheet were shown by Rem-Cru Titanium, Inc. The many good qualities of this metal may parallel the brilliance of the titania jewel, cut from an artificial crystal of TiO_2 made by the same technique as used for manufacturing jewels for instrument bearings. One was given each day to the winner of a draw. It has good optical qualities and might almost be mistaken for a diamond of yellowish cast.

Progress in metal seems unending and next year may well be the year of zirconium. Both the metal and its oxide ZrO_2 and silicate $ZrSiO_4$ offer much to the metallurgist. The conversion of zirconia ZrO_2 from the monoclinic to the cubic form has produced a super-refractory with excellent resistance to thermal shock. Metallic zirconium, displayed by Titanium Alloy Mfg. Division of National Lead Co., offers much along the lines of corrosion resistance. Its other interesting properties and its general metallurgy will be the subject of a day-long seminar sponsored by the U. S. Atomic Energy Commission at the ⊕ Western Metal Congress in Los Angeles next March.

It had taken six hours to inspect but cursorily some 34 exhibits of nonferrous nature. It is questionable whether anyone desiring to cover the whole exposition could do it in the entire week. Certainly a complete coverage would require more than one man's time. Many executives, metals engineers, and supervisors of operations who could not attend this national event or could spend but a few hours in it must feel regret at missing so fruitful an opportunity for stimulating mental activity by contact with some of the brightest minds of the metal world.

H. J. R.

Digging Deeper Into Metal Structure

The more erudite members and friends of ⊕ and the associated societies (physical metallurgists, scientists, or researchers into the solid state) were ga-ga about the so-called field emission microscope demonstrated by Erwin W. Muller in his feature lecture of the Seminar on Modern Research Techniques in Physical Metallurgy. The apparatus consists essentially of a cathode-ray tube, about

the size and shape of a Christmas tree bulb, wherein the electrode emitting the electrons is a tungsten needle, sharpened to the finest possible point, and then heated hot enough so the end assumes a spherical shape from surface tension — a hemisphere with radius on the order of 0.000005 in. Electrons can be discharged from this tungsten needle by a strong electric field and these fly away in paths normal to the surface. They fall on the glass end of the tube — also a sphere, concentric with the end of the electrode — and there they activate a fluorescent coating. "Magnifications", therefore, are measured by the ratio of radius of tube-end to radius of electrode-end, and are on the order of 500,000.

A part of the demonstration was a motion-picture film taken while trying to explain the patterns observed on the fluorescent tube-end. When the tungsten electrode was at 2000° F. a pattern of dark spots appeared in a phosphorescent background, spots which were symmetrically arranged around two axes at 90°. As the temperature was varied, the pattern remained substantially unchanged, and the lecturer identified various spots with the principal crystallographic planes of the tungsten, the inference being that perpendicular emission was rather deficient from these planes as compared with emission from atoms along more oblique or intermediate planes. (Emission from crystallographic *planes* in a *sphere* was explained by the fact that the tip is a single crystal, and the sphere contains in its surface all possible crystal faces as tiny planes.) At any rate, the fluorescent background showing on the tube-end was altered considerably when an infinitesimal amount of carbon was placed on the hot tungsten electrode, and this was said to be due to differences in electron emission by carbon and tungsten atoms. In similar experiments made with molybdenum points, the symmetrical arrangement of principal spots was unchanged, even though the temperature was increased, *until* 2700° F. was passed, when the pattern suddenly transformed to a new one wherein the dark spots arranged themselves hexagonally, with three axes of symmetry at 60°. "That," said the lecturer, represents the formation of molybdenum carbide. Previously the carbon was either adsorbed on the surface or dissolved as an atomic dispersion."

It is hoped that the field emission microscope will become a powerful tool for study of surface reactions — corrosion, for example, since oxygen emits very few electrons and causes additional dark spots in the general luminescent ground. Furthermore, since electrons can be drawn electrically from the tip at room or subnormal temperature, the structure of adsorption layers consisting of many gases or chemical compounds may be resolved by this technique.

Machines for Searching Metal Literature

Members of the Society who use the abstracts in *Metals Review* know that they are coded by the symbols of the "ASM-SLA Classification System for Metallurgical Literature", devised in 1950 by a joint committee of the American Society for Metals and the Special Libraries Association (Metals Section). A card with appropriate holes punched around the edges was also designed for card indexes using this system, and this provides a simple, rapid and accurate scheme for needling-out literature references. (Beyond 10,000 items efficiency breaks down because of limitations imposed by hand sorting.)

This classification has been fairly widely used by men who compile their own reference files; half a million cards have been printed and distributed during the past two years. An additional measure of its success is its utilization in the library of the Kaiser Aluminum & Chemical Corp., and its recent adoption by the U. S. Atomic Energy Commission and British Iron and Steel Research Assocn.

A well-attended meeting at the National Metal Congress in Philadelphia considered further extension of this demonstrated usefulness to much larger collections, substituting automatic sorting equipment for the manual needling operation. Some experiments have already been made with standard I.B.M. equipment now available at Battelle Memorial Institute, which indicate that the ASM-SLA Classification could readily be used with minor adjustments in the coding system.

Standard business machines, however, are designed primarily for statistical purposes and computation, and lose efficiency when indexing, searching and correlating technical information. A more or less elaborate "memory machine" is required which can recognize patterns of holes punched in cards, patterns of transparent spots on photographic film, or

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magnetized spots on a tape — each pattern being one aspect of a literature reference.

Such expensive equipment can probably be operated economically by a large information center which would handle inquiries for bibliographies, or copy documents or answer specific questions with dispatch. Such mechanized centers of information will be a necessity if future scientists are to have the full benefit of prior knowledge stored in libraries. Fremont Rider has produced the frightening statistic that research libraries have been doubling in size every 16 years with such regularity that a parabolic growth curve is indicated. However, a welcome checkrein to this documentalist's nightmare of some day drowning in a sea of printed words was provided by Ralph Shaw, librarian at the Department of Agriculture, who reminded us that such a curve cannot continue indefinitely. If it did, production of automobiles, for example, which approximately doubled every two years for a period of 20 years, would now amount to 1000 new automobiles *every year* for every man, woman and child in the United States!

Nevertheless, the literature problem is a massive one, and traditional library techniques must eventually be supplemented by mechanized equipment. Just how far such machine techniques have already progressed was indicated by James W. Perry of M.I.T.'s Center for Scientific Aids to Learning. He observed that storage of information is only the first step; from this the machine can recall isolated facts. It must also associate *related* ideas — a function which, in conventional indexing, depends upon human memory. It is when the search is directed toward developing *new* associations of ideas that the conventional indexing system fails.

No machine, of course, can bring forth any more information than has been put into it, but with a properly thought-out indexing and coding system it can call up new relationships among the ideas it stores. Likewise — and this is most important — the searcher need not use exactly the same terminology as the indexer who put the information into the machine, since the intermediate machine language or coding system would automatically translate synonyms! Such translation would require a code dictionary, which can be made up by feeding words and phrases into an automatic coding device. M. R. H.

Any Cheap Titanium Tomorrow?

The well-attended meetings on titanium and its alloys held by the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers was fortunate to have as chairman Matthew A. Hunter, professor emeritus of metallurgy at Rensselaer Polytechnic Institute, who as a young investigator in General Electric's research laboratory was the first to make any of the pure metal. This was in 1906. In a charming account of these early attempts to find a metallic filament for incandescent lamps (the melting point of titanium was reputed to be around 6000° C., far beyond that of tungsten, molybdenum and tantalum which were also under investigation), he told how ductile beads of practically pure titanium were secured by reacting titanium tetrachloride with metallic sodium inside a bomb. When a chunk of this metal was forged into a rod and electric current passed through it, it melted at about 1800° C. "By this one act the glamour attached to titanium metal as a filament material disappeared, to the great disappointment of myself and G.H.Q. of the G. E. Co."

After remaining quiescent for about 40 years, interest has sprung up within the last decade, principally because the U. S. Defense Department has financed a very large amount of laboratory investigation and subsidized commercial operations which are now making five or six tons of metal daily, with 5000 tons anticipated in 1952. Under these conditions it was proper that one of the meetings was monopolized by representatives of the armed services, who described titanium's use for weight saving in airborne and G.I.-borne equipment, and the other meeting by representatives of producers, who generally dwelt upon their success in making bigger and bigger titanium ingots, sufficiently free from gaseous contamination as to be readily fabricated in ordinary mill operations.

Nearly all the titanium is now produced by a process for zirconium devised by W. J. Kroll when with the U. S. Bureau of Mines in 1939, wherein the tetrachloride is reduced to sponge by magnesium. The sponge is now consolidated by powder metallurgical methods, or by arc melting in helium atmosphere. One of the producers relies on the van Arkel-de Boer method: TiI_4 vapor is thermally decomposed on a hot tungsten wire, even-

(Continued on p. 179)

Reviewed by Arthur H. Allen, Technical-Business Consultant, Cleveland

Fretting Corrosion — What It Is, Its Cause and Possible Preventives

SURFACE FAILURES which have been widely observed when tightly fitting metal parts undergo slight relative motion have come under the scrutiny of investigators and metals engineers for well over 20 years, yet no unanimity of explanation or remedy has been reached. A variety of descriptive names has been advanced — false brinelling, wear oxidation, friction oxidation, chafing fatigue and, more recently, fretting or fretting corrosion. This variety itself may be a measure of the uncertainties surrounding the phenomena.

The service failures are characterized by surface stain, pitting and the generation of oxides. One of the first instances to come to attention, during the early thirties, was in connection with automobiles shipped by rail to the West Coast; failures of mechanical bearings on the wheels were reported after only a few miles of driving. J. O. Almen of General Motors Corp. (*Mechanical Engineering*, June 1937) and D. A. Wallace of Chrysler Corp. (*SAE Transactions*, February 1940) concluded that the damage occurred during transportation of the autos while their weight rested on the wheels blocked on freight-car floors. Motion of the car caused slight sidewise vibrations (as far as end-play in the wheel bearings would allow), this being sufficient to cause balls and rollers of the bearings to embed themselves in the races. The action was then described as "false brinelling".

Similar failures occurred in bearings for aircraft control pulleys where the outer race oscillated through a very small arc instead of making complete revolutions. Hudson T. Morton, standards engineer for Fafnir Bearing Co., mentions them in a 1949 engineering report, along with other examples in electric motor shafts, auto spring shackles, kingpins, rocker arms, variable-pitch propellers, landing wheels, cam followers in textile machinery, and miscellaneous machinery and motors during transport.

He called the damage "friction oxidation" and theorized as follows: Heavy loads squeeze the lubricant from the contact areas of balls within the bearing races. Rotation pushes extra lubricant ahead of the ball, and reversing action starts the ball rotating into the area free from lubricant, with resultant metal-to-metal contact accompanied by "welding", skidding and heat. If the associated decomposition of the grease forms any acids, these increase the rate of oxidation. As a corrective he recommended that for bearings subjected to such oscillations the design loads should be reduced to 50% (preferably to 35%) of the values given in catalog tables for rotations per minute equal to half the reversals or oscillations expected per minute. He also recommended that the total movement of the bearing should be sufficient to turn the balls 180°, and that fluid lubricants with low viscosity, strong adhesive properties and oxidation resistance should be specified.

Reports on wear oxidation appeared in *Transactions* in 1930 and 1935, Vol. 18 and 23, by M. Fink, S. J. Rosenberg and L. Jordan. In Great Britain, G. A. Tomlinson reported on the rusting of steel surfaces in contact as early as 1927 in *Proceedings* of the Royal Society (London), Vol. 115, No. 771, while the same researcher cooperated with P. L. Thorpe and H. L. Gough in analyzing the fretting corrosion of closely fitting surfaces in the *Proceedings* of the Institution of Mechanical Engineers (London) for May 1939, Vol. 141, No. 3.

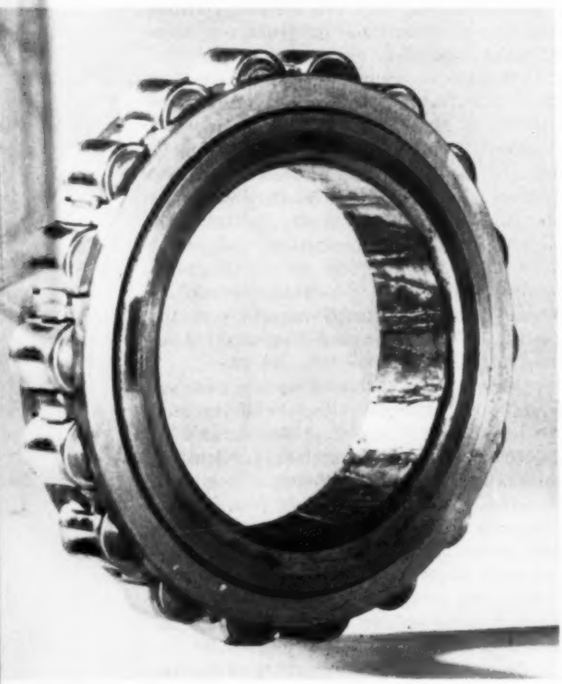
Strangely enough, fretting corrosion appears to be worse, other factors being equal, the better the original fit of the surfaces involved. This makes the problem particularly serious in the aircraft industry where close fits are common; as a matter of fact, fretting corrosion has been discovered in practically new aircraft engines, on tooth surfaces of the main shaft coupling, on gear keys and shafts, and particularly between shaft and inner race of rolling contact bearings, as shown in Fig. 1.

Hence it was only natural that the Na-

tional Advisory Committee for Aeronautics has sponsored an extensive research on the problem, both on its own and on the outside. Some of this work was done by B. W. Sakmann and B. G. Rightmire at Massachusetts Institute of Technology, and was published by the N.A.C.A. as Technical Note 1492 in June 1948. They vibrated a small flat sample across a stationary hemisphere, using in succession many ferrous and nonferrous metals, sometimes in pairs, sometimes dissimilar materials. They sought to determine specifically whether chemical action was important in the fretting of metal surfaces and whether such action would improve the eventual corrosion resistance of the metals investigated.

Tests were made with the same pairs of materials in air, in vacuum, in oxygen, and in helium under identical conditions of load and slip. With nearly all samples, less damage was observed in vacuum than in air, and less in an inert atmosphere than in oxygen. In no instance was the damage in vacuum greater than in air although the friction was usually greater.

Fig. 1 — Severe Fretting Corrosion Inside the Inner Race of This 2½-In. Bearing, Exactly as It Appeared When Removed From an Engine Shaft



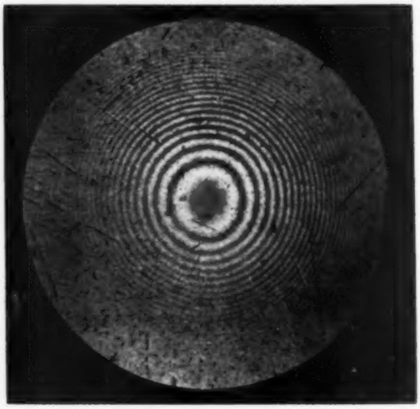


Fig. 2 — Photomicrograph (With Vertical Illumination, Red Filter, About 50 ×) of a Chromium Steel Ball Through Glass Slide, Showing Interference Bands Surrounding Contact Area

Conclusions were that chemical action is of primary importance in fretting corrosion and that oxide formation does not give any protection to the metals but rather increases the rate of wear; that in most observed instances of fretting, wear between vibrating surfaces was so severe that any protective oxide films were rubbed off and acted as an abrasive between the vibrating surfaces. Exclusion of oxygen from the surfaces by such means as oil or grease was considered outside the scope of the present investigation.

Realizing the growing complexity of the problem and the divergence of various viewpoints as to cause and mitigation, Douglas Godfrey, of the N.A.C.A.'s Lewis Flight Propulsion Laboratory in Cleveland, determined to take a different tack. In his explorations of the mechanism of fretting corrosion during the past two years, he has utilized microscopic observations and color-motion photomicrographs. N.A.C.A. Technical Film 23, a 16-mm. color film with sound, is little short of spectacular and would be a rare treat for most metallurgists and metals engineers to see. It may be obtained on a loan basis by writing to the National Advisory Committee for Aeronautics, 1729 F St., N.W., Washington 25, D. C.

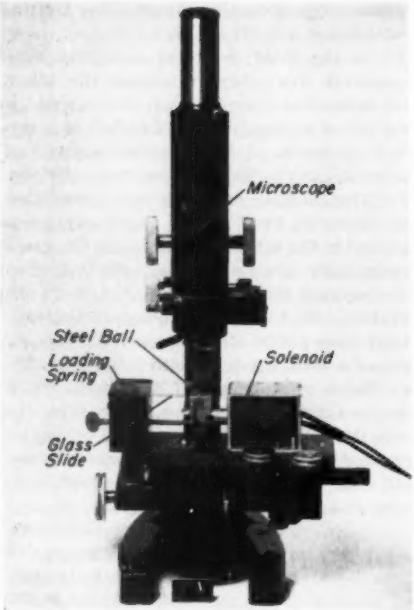


Fig. 3 — Apparatus for Inducing Fretting Corrosion in Specimens Under Microscopic Observation. In the setup shown a steel ball is rubbed against the bottom of the glass slide

Godfrey's work appears to throw entirely new light on the mechanism and its prevention, and will be examined at some length here. The first published material on the investigation was N.A.C.A. Report 1009 and this was followed by Technical Notes 2180 and 2628, coauthored with Edmond E. Bisson, and devoted, respectively, to work on molybdenum disulphide as a fretting-corrosion inhibitor and the mechanism of its bonding to various materials. The three reports were consolidated and somewhat amplified in a paper the two engineers presented in April before the American Society of Lubrication Engineers.*

Reviewing the various theories which have been advanced, Godfrey and Bisson point out that attrition, surface welding, and vibrational fatigue suggest that fretting corrosion is a physical action, whereas electrolytic corrosion and frictional oxidation suggest that the cause is chemical. This divergence may be resolved simply by the sequence of the events — the hypothesis of physical action suggests that the material is rubbed off the surface and then oxidized; the hypothesis of chemical action suggests that the surface first is oxidized or corroded and the oxides then rubbed off.

In the N.A.C.A.'s microscopic investigation the specimens included various metals, as well as such noncorrosive materials as glass, quartz, ruby and mica — the latter group of oxide minerals being chosen because their fretting would show whether the primary action was physical or chemical. Furthermore, such nonmetallic materials simplified analysis of "debris", and glass in particular made the color-motion photomicrographs possible.

Fretting was induced by the simple apparatus shown in Fig. 3, which vibrates a convex (usually spherical) surface in contact with a flat surface at frequencies of 120 cycles per sec. through an amplitude of 0.001 in. and under a load of 0.2 lb. The vibrating action is induced by a solenoid which moves a horizontal plunger to and fro. The plunger has a cavity for carrying a spherical specimen (in Fig. 3 a steel ball) which rubs against the bottom of a flat specimen (in Fig. 3 a glass slide). This flat specimen is held stationary at one end and loaded vertically by a flat spring, causing it to exert a load of approximately 0.2 lb. on the ball. This apparatus rests on the mechanical stage of a microscope, and the contact area can be observed at 140 diameters magnification with either vertical or oblique illumination after the flat specimen is removed. (With transparent flat specimens, the contact area is readily located since it is surrounded by concentric interference bands such as shown in Fig. 2.)

All specimens were cleaned thoroughly just before mounting. Metal pieces were degreased in an organic solvent, scrubbed with surgical cotton in a paste of levigated alumina, rinsed in tap water, rinsed in 95%

*A symposium on fretting corrosion, sponsored by the American Society for Testing Materials at its annual meeting in June, elicited several contributions of practical significance. J. R. McDowell of Westinghouse Research Laboratories, in a paper entitled "Fretting Corrosion Tendencies of Several Combinations of Materials", found no combination of materials which could resist fretting; the only way to prevent fretting was to insert (where possible) a rubber gasket between the vibrating surfaces. E. W. Herbeck, Jr., and R. F. Strohecker of the Texas Co. in a paper "Effect of Lubricants in Minimizing Fretting Corrosion" found that greases with a worked penetration of 320 or more and good "feedability" would minimize fretting corrosion.

Action of Metal on Glass

alcohol, and air dried. Glass, ruby, quartz and mica were cleaned in fresh acid solution, rinsed in tap water and distilled water, and then oven-dried.

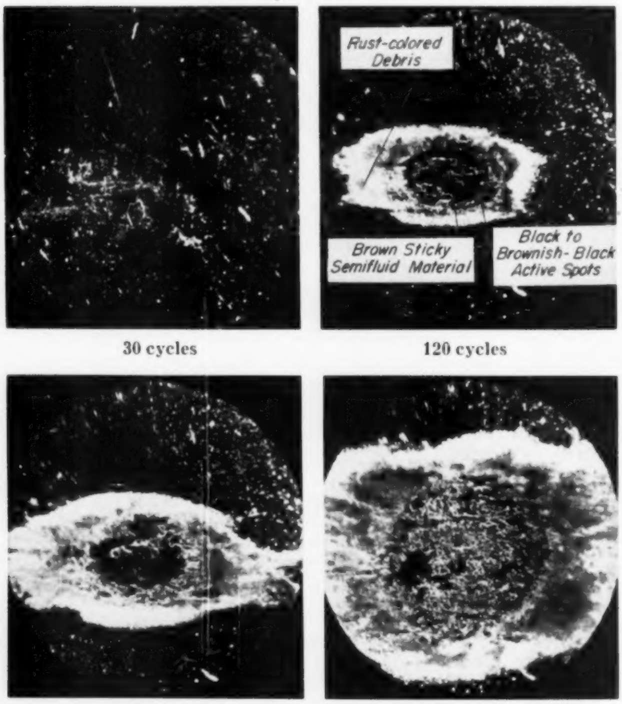
Experiments at 120 cycles per sec. were divided into three groups — metal flats against metal balls, metal against nonmetal, and nonmetal against nonmetal. In the first or preliminary group, mild steel, chromium steel, stainless steel, copper and aluminum were vibrated against mild steel, mainly to ascertain whether the tests had satisfactory reproducibility.

In the second group of experiments each of the five metals was vibrated against glass microscope slides, mica and lucite, and extensive observations were made with ½-in. balls of S.A.E. 52100 steel against glass slides. Glass, of course, had the advantages of being rigid, noncorrosive and transparent. Incidentally, glass not only produces fretting on steel but is itself attacked.

In the third group of materials, each nonmetal was vibrated against the other. All specimens were shaped into convex or flat pieces as required and finished to a surface roughness of 1 to 3 micro-inches, root mean square, by fine grinding and polishing.

The number of cycles was determined by measuring the length of time current was applied to the solenoid. Where the flat specimens were not transparent, the vibration was induced for periods of 1, 2, 4, 8, 16, 32, 60, 120, 180, 300 and 600 sec. cumulatively. After each period the flat specimen was removed and the spots on both convex and flat specimens microscopically examined. With the transparent specimens, of course, the complete action could be viewed or photographed easily. Special jigs insured that flat and ball were in contact at identical positions in each part of the total run.

Fig. 4 — Photomicrographs Showing Progressive Stages in Fretting Between Glass Microscope Slide and Chromium Steel Ball. 60 ×



30 cycles

120 cycles

240 cycles

1200 cycles

In the metal-to-metal tests, each pair of specimens showed fretting within approximately 300 sec. ($300 \times 120 = 36,000$ cycles) and produced the characteristic debris and wear area. The pattern of the spot on the flat surface was always similar to that on the convex surface. Results could be duplicated readily.

Four photomicrographs of the contact area at various stages of fretting caused by vibrating a chromium steel ball against a glass specimen are shown in Fig. 4. First indication of fretting came within ¼ sec. (30 cycles), in the form of a small, black, irregular spot on the ball, which grew steadily in size and became discontinuous. A brown, sticky, semifluid oxide then appeared within the contact area, spread over the glass and adhered tenaciously to it. This oxide shared the contact area with the black material. A rust-colored, fine, dry oxide also was formed, being extruded from the area in increasing quantities and accumulating at the edges.

Active black spots shifted

position as the phenomenon progressed because of disintegration of peaks bearing the load for the moment. After about 40,000 cycles the action stabilized to a steady growth with continued generation of material in the black spots surrounded by brown semifluid oxide and the fine powder oxide.

The black color indicated finely divided iron, a fact confirmed by its subsequent change to dark brown and then to rust brown. (Finely divided iron, ferrous oxide, FeO, and ferrosoferric oxide, Fe_3O_4, are black, while ferric oxide, Fe_2O_3, and its hydrated form, $Fe_2O_3 \cdot H_2O$, are reddish.) The fretting debris was identified by electron diffraction as Fe_2O_3, and the color changes that occurred pointed to the progressive oxidation of the iron. Fretting thus is apparently initiated by the loosening by adhesive forces of extremely fine and presumably virgin material that is extruded from the moving area in contact and reacts with oxygen simultaneously.

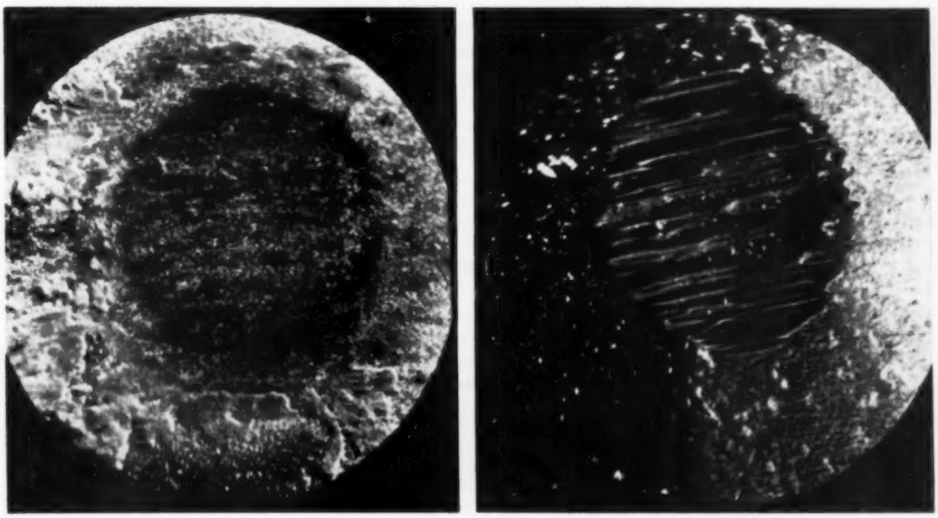
Examination of the ball after the experiment revealed a flat oxide-encrusted spot, Fig. 5, which on cleaning proved to be an abraded flat spot, shown at the right of Fig. 5. When the sticky oxide was cleaned from the glass, a striated cracked area was disclosed, apparently of appreciable depth and irregularity.

Introduction of a film of pure mineral oil between the surfaces multiplied about 50-fold the time for first evidence of fretting. The delay was welcomed since it provided a slow-motion study of the process, indicating that oxides were produced, just as in the "dry run". Once the action was well under way, the effect of the oil was reduced.

Refutation of the theory that oxidation is a primary cause of fretting was furnished by one test in which flame-cleaned platinum foil supported by a steel ball was vibrated in contact with clean glass. Black powder was generated in the characteristic way but the debris remained black and that adhering to the glass could be removed only after 4 hr. in aqua regia. Color, acid resistance, electron diffraction pattern and source indicated the material to be finely divided platinum (platinum black). The metal will not, of course, oxidize in air at any temperature.

Subsequent runs proved that fretting can occur with nonmetals against nonmetals. The susceptibility to fretting of nonoxidizing material such as glass, quartz, ruby, mica and platinum proves that oxidation is most certainly a secondary factor. Finely divided and apparently virgin material is first produced; it oxidizes almost spontaneously on metals, possibly because of the greater chemical activity of the small particles.

Fig. 5 — Photomicrographs Showing Fretting Area on Chromium Steel Ball After 3000 Cycles, Before Cleaning (Left) and After. 90 ×



Remedies for Fretting Corrosion

Oxide formation was induced at extremely low speeds (hand operation of microscope stage) and light loads where the dissipation of heat was fast enough to rule out the occurrence of local hot spots. Therefore, the possibility that fretting is caused by rubbing off a regenerative high-temperature oxide film impresses Godfrey as unlikely.

Turning now to remedial measures, these investigators reason that since fretting is caused basically by the high adhesive forces which remove virgin material, it could be prevented by any means that decrease these forces — to wit, the insertion of any film of low shear strength, either liquid or solid. The problem is one of maintaining such a film under the severe scrubbing action on small contact areas and under low-amplitude vibration. Toughness and tenacity are additional film requirements.

Molybdenum disulphide is a solid film lubricant with the desirable properties of high load-carrying capacity and ability to minimize metallic adhesion under high pressure, tenacity for steel, low friction coefficients over a wide range of velocities, and thermal stability. It was a logical choice for further research as a fretting inhibitor.

The first question was how best to apply the film to steel specimens. Six methods were examined: *(a)* dusting with MoS_2 powder; *(b)* rubbing with MoS_2 powder by fingers; *(c)* immersing in a mixture of MoS_2, distilled water and aerosol; *(d)* immersing in a mixture of MoS_2 and S.A.E. No. 10 oil; *(e)* coating with a mixture of MoS_2 and heavy grease (lime-soap base); and *(f)* bonding with MoS_2 by rubbing a mixture of powder and corn syrup into intimate contact with cleaned hot metal.

Tests using all methods were made, with apparatus similar to that described in the earlier microscopic observations. Specimens included steel balls against steel flats, and steel flats against each other for four of the more promising coating methods. Results are consolidated in Table I.

Summary — Fretting corrosion is a surface deterioration which may occur when closely fitting metal (or nonmetal) surfaces move only minutely with respect to one another, as for example in vibration of machine parts. Factors influencing this surface disturbance are motion, oxygen, lubrication, hardness, load, materials and surface roughness.

Evidence points to the fact that fretting is caused, not by oxidation, but by the loosening, due to inherent adhesive forces, of finely divided and evidently virgin material. On most metals this material will oxidize rapidly as it is extruded from the contact area.

Effectiveness of molybdenum disulphide as an inhibitor appears promising. A bonded type of coating can be made by mixing the MoS_2 powder with a resin-forming liquid, applying the mixture to the cleaned metal parts and then curing to a dry, thin, hard film. While the work herein reviewed is all of a laboratory nature, it was definitely aimed at determining correctives for field troubles arising from fretting corrosion in aircraft engines.

Table I — Fretting Corrosion Tests With MoS_2 Inhibitor

Surface Condition	Cycles for First Corrosion	Condition of Contact Area After Test
Steel ball against glass flat		
Clean	1 to 30	Instantaneous fretting
MoS_2; dusted	72,000	MoS_2 formed smooth bearing surface, then rubbed away
MoS_2; rubbed	21,600	MoS_2 smeared thinly, then rubbed away
MoS_2, water and aerosol; immersed	21,600	MoS_2 visible only in surrounding area
MoS_2 and oil; immersed	86,400	MoS_2 visible only in surrounding area
MoS_2 and grease; coated	216,000	MoS_2 visible only in surrounding area
MoS_2 and syrup; bonded	28,000,000	Coating formed smooth bearing surface, then brown stain appeared
Steel flat against steel flat		
Clean	less than 100	Immediate fretting
MoS_2; dusted	100,000 to 160,000	Dry red oxide and stain
MoS_2 and oil; immersed	700,000 to 760,000	Brown-black debris and spotty surface failure and stain
MoS_2 and grease; coated	1,500,000	Brown-black debris and spotty surface failure and stain
MoS_2 and syrup; bonded	9,850,000	Smooth, shiny bearing areas formed, then brown powder appeared

By Allen G. Gray, Consulting Editor to Metal Progress

Treatment of Metal Finishing Wastes

Proper and economical disposal of metal finishing wastes is a problem which has grown vastly in importance in the past few years. Stream pollution, impairment of sewage systems, and damage to sewage disposal mechanisms may result from improper disposal. In many localities restrictive legislation is enforced vigorously. It is therefore important that the metals engineer decide which of the practical methods is best for the types of finishing, local conditions, and the economic factors of plant investment and operating costs.

Facilities for collecting and treating wastes from the various plating, pickling, bonderizing, cleaning and anodizing installations throughout the Erie Works of the General Electric Co. were described by John W. Townsend, of Consoer, Townsend and Associates, consulting engineers of Chicago, at the Sixth Industrial Waste Conference held at Purdue University. Wastes at this plant are separated into the following three classifications for collection and treatment: *(a)* spent acid; *(b)* cyanide-bearing rinse water; *(c)* metal-bearing rinse water.

All spent acids requiring neutralization with lime are isolated from the main drains at each pickling installation as a precaution against accidental spillage or dumping, and are pumped through acidproof pipes to underground storage. All acids to be hauled from remote locations by tank truck, and acids requiring chemical reduction prior to neutralization with lime, are discharged into a second underground tank; these storage tanks are designated "Pit P-1" and "Pit P-2" in Fig. 1. The volume of spent acids at this plant amounts to 25,000 to 30,000 gal. per week, and consists of nitric, hydrochloric, citric, oxallic, and chromic acids.

The acid storage tank (Pit P-1) is used to intercept all pumped acids not requiring reduction with ferrous sulphate or sodium bisulphite. The tank has a hopper bottom and is constructed of concrete with a 4-in. carbon brick lining; its capacity is 15,000 gal. Tank Pit P-2 has a capacity of 10,000 gal. and is constructed similar to Pit P-1 except that the concrete bottom and walls are lined with 8 in. of acid resistant brick.

Each of the tanks is equipped with an "Infilco Vorti-Mix" unit designed to create a vortex movement and thoroughly mix a lime slurry into the acid wastes. Equipment for the feeding of lime consists of an "Infilco" feeder and slaker having a capacity of from 200 to 2000 lb. per hr. and a steel elevated lime hopper 18 ft. in diameter with a capacity of about two cars of lime. Ferrous sulphate or sodium bisulphite, which is used for reducing the metal content in certain of the acid wastes, is fed into Pit P-2. Centrifugal pumping units eject the wastes from the "neutralized acid tank" to the rinse water treatment plant for subsequent dewatering and disposal.

Other Methods for Waste Acid Treatment

H. W. Gehm (*Chemical and Metallurgical Engineering*, October 1944, p. 124) and A. L. Reidel (*Chemical Engineering*, July 1947, p. 100) have described plants where acidic wastes are passed up through beds of crushed limestone for neutralization. Gehm concluded that a flow rate of 20 to 100 gal. per min. per sq.ft. could be used with beds 1 to 4 ft. deep, provided the sulphuric acid concentration does not exceed 5000 parts per million. Reidel recommended a flow of 40 to 50 gal. per min. per sq.ft. through an 18 or 20-in. bed. This treatment will increase the pH to about 5.0, and therefore prevent any appreciable corrosion of the sewer lines. However, the formation of calcium sulphate and metallic hydroxides on the limestone has favored the use of high calcium lime for the neutralization of acid pickle waste solutions.

For plants using less than about two tons of lime per day the installation of a dry feeder may be the simplest way to treat the waste acid. It may be worth while to consider the use of cheaper quicklime and the installation of a lime slaker, particularly if larger quantities of neutralizing agent are required. In the lime feeder and slaker, pebble quicklime and water are fed at a controlled rate into the slaking compartment where they are mixed for a sufficient time to slake the lime uniformly into a slurry

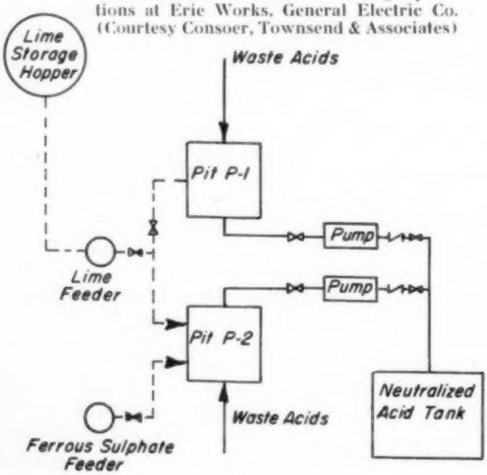
which can neutralize waste almost instantly. A mixing tank having a detention time of approximately 5 min. will produce a neutralized effluent, provided an agitator is used which turns over the contents every 30 sec.

TREATMENT OF CYANIDE WASTE

Rinse waters containing cyanide, which are collected from the various plating installations throughout G. E.'s Erie plant, may be discharged to any one of three reinforced concrete tanks, each having a volume approximating 200,000 gal. This capacity is ample to retain the anticipated cyanide waste produced in 24 hr. It is treated with lime and chlorine by the batch, with operations so scheduled that one tank will always be available for receiving the rinse water waste.

Each tank has been equipped with a mixer which operates for 6 hr. daily. Following this treatment with lime and chlorine the batch is allowed to settle for 2 hr., after which the clarified supernatant liquor, which occupies the upper two thirds of the tank, is decanted off slowly (16 hr.) to an outfall conduit discharging into Lake Erie. Special equipment has been installed to insure a uniform discharge of supernatant liquor over the 16-hr. decanting period. The lime sludge remaining in the lower third of the tank is then pumped into the "Cyclator" tank for subsequent concentration and removal with the metal waste sludge (see Fig. 2).

Fig. 1 — Flow Diagram for Treatment of Acid Wastes From Metal Finishing Operations at Erie Works, General Electric Co. (Courtesy Consoer, Townsend & Associates)



Hydrated lime, used for raising the pH of the cyanide waste to 8.5, is fed with an Infilco feeder having a capacity of 200 lb. per hr. Chlorine facilities consist of Wallace and Tiernan visible vacuum chlorinators, two chlorine injector water pumps, chlorine evaporator and scales to measure chlorine used from ton containers. In order to avoid the addition of a large volume of water from an outside source, as would normally be required for the chlorinator injectors, piping connections are made to each of the three cyanide tanks and this water is pumped to the injectors.

More and more plant executives are finding that alkaline chlorination is the most practical treatment of cyanide wastes. Using chlorine, the process can be adapted to a continuous flow treatment method, as well as batch application. It also has the advantages of destroying the last traces of cyanide as quickly as higher concentrations. In the chemical reactions involved, the oxidation by chlorine apparently proceeds in two steps in the alkaline medium. In the first step the cyanide is oxidized to cyanate. Theoretically, 2.73 weight-units of chlorine are necessary to oxidize 1 weight-unit of cyanide to cyanate. (In practice, about 4.0 weight-units are used.) If sufficient chlorine is added, the cyanide is completely oxidized to carbon dioxide and nitrogen. For this complete oxidation, theoretically, 6.83 weight-units of chlorine are necessary; in actual practice, something of the order of 8 weight-units of chlorine are used. The pH of the solution should be maintained at 8.5 to 9.0 during treatment. Figure 3 shows a typical Wallace and Tiernan chlorinator for use in cyanide treatment.

At Delco-Remy Division, General Motors Corp., cyanide rinse water following two reclaim rinses is treated by alkaline chlorination in one of the rinse tanks in a zinc-plating machine. In discussing the details of this disposal operation before the conference at Purdue University, C. F. Hauri, plating engineer at Delco-Remy, pointed out that the rinse water is pumped from the tank to be chlorinated through the injector of the chlorinator, whence it is returned to a diffuser placed in the sump of the rinse treatment tank. This sump also contains the electrodes of the pH meter. Alkalinity in the treatment tank is adjusted by adding caustic to maintain a pH of 8.5 to 10.

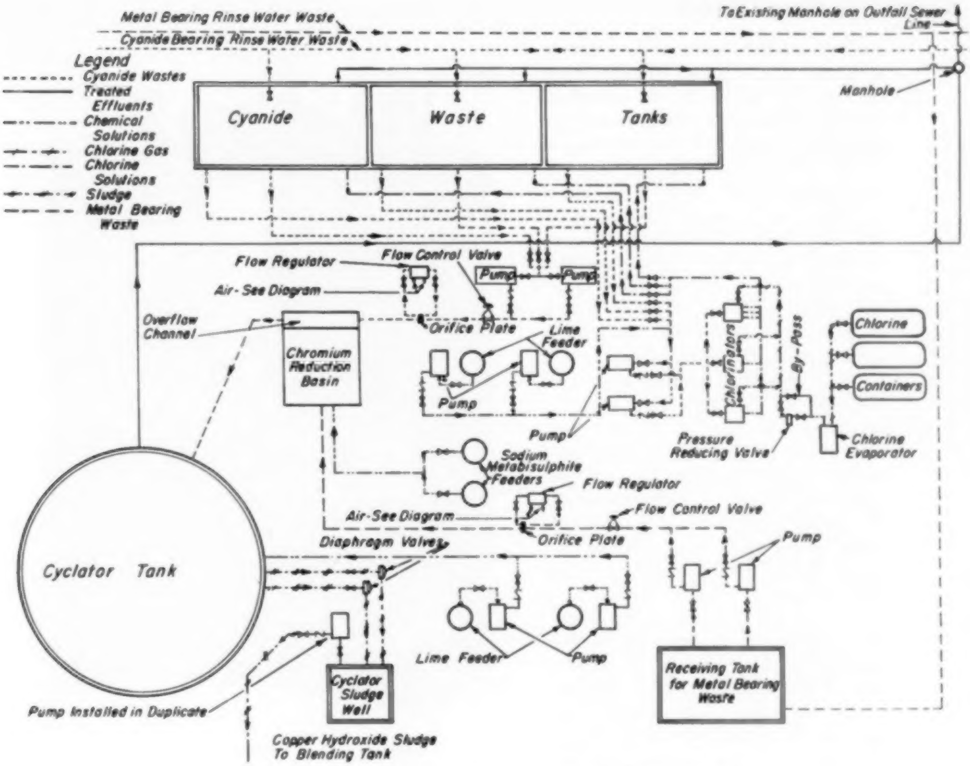


Fig. 2 — Flow Diagram for Rinse Water Treatment at Erie Works. (Courtesy Consoer, Townsend & Associates)

The treatment operation is continuous, since the water in the tank is being constantly recirculated during the operation. Fresh water is added to the rinse tank at a rate of about 1 gal. per min. so that a like amount overflows continually to the sewer. (Initially it was thought that the chlorination of the rinse water proceeds for perhaps 4 hr., followed by discard to the sewer.) Experience with the equipment actually in operation was the basis for fixing the amount of overflow; fresh water replaces the solution every 2 hr. This scheme makes it unnecessary to discard batches and results in less downtime for the plating operation.

Metal-Bearing Wastes — In the waste treatment system designed for the Erie Works of the General Electric Co., all acid rinse waters containing chromium, copper and aluminum salts are collected at each individual installation in concrete sumps lined with acid brick and pumped by acid resistant pumps through rubber-lined steel pipe to a receiving tank at the treatment plant. This tank has a capacity of 232,000 gal. and is equipped with air jets and scouring plates designed to effect mild agitation so that representative samples of the waste may be obtained for determining chemical additions and feeder settings.

The wastes are pumped from the receiving tank during a 6-hr. period daily to the chromium reduction basin wherein the hexavalent chromium is reduced either by sodium bisulphite or ferrous sulphate. This basin provides for a retention period of 10 min. and is equipped with a mixer. Wastes then flow over stainless steel weirs into the "Cyclator" tank for subsequent treatment with lime.

Cyclator — Such metal-bearing rinse waters, after having passed through the chro-

Recoveries From Sludge

mium reduction basin, are combined with the sludge being pumped from the cyanide tanks in the overflow channel adjacent to the chromium reduction basin and are discharged to the primary mixing chamber of the Cyclator tank. Here, lime slurry is added in a manner which will provide intimate contact and rapid chemical reaction. Following this reaction, the liquid is separated from the solids and the clarified liquid passes to the outfall sewer over a weir around the tank's circumference.

This Cyclator treating tank was designed for any flow rate up to a maximum capacity of 825 gal. per min. from a minimum of approximately 100 gal. per min. It is a circular reinforced concrete structure 50 ft. in diameter for containing liquid about 14 ft. deep. The mechanism within this tank provides for primary and secondary mixing and reaction chamber; a separation chamber; means for producing double circulation, one part of which consists of the primary mixing chamber while the other part passes out through the secondary mixing chamber and discharges laterally into the separation chamber at an upper level with downward flow carrying unsedimented solids therefrom through the lower part of the separation chamber back into the primary mixing chamber.

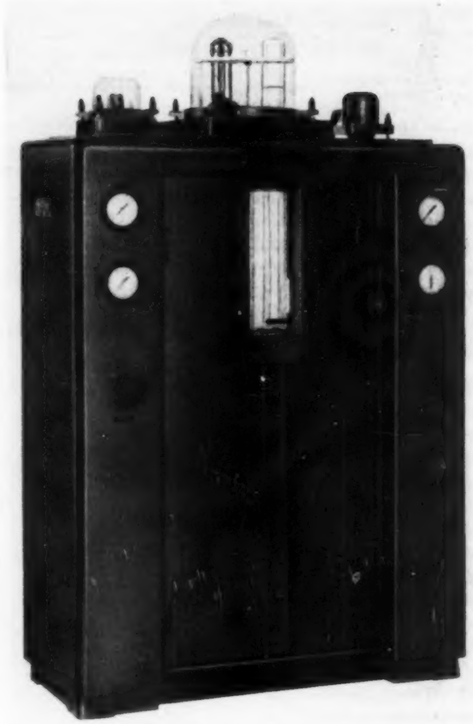


Fig. 3 — A Typical Chlorinator Made by Wallace & Tiernan Co. for Treatment of Cyanide Wastes

A rotating scraper mechanism moves the settled sludge to two sumps in the bottom of the tank, whence it is removed to a sludge well through two 4-in. discharge lines which are provided with timer-controlled diaphragm blow-off valves with adjustable timing. An automatic hydraulic skimmer removes surface scum or cutting oil which might be present in the waste rinse water, to a skimmer plate at the periphery of the tank, from which it is removed by an automatic valve to an adjacent sump.

Treatment of Sludge — Copper hydroxide sludge, resulting from the Cyclator tank treatment, is discharged daily over a 6-hr. period from the Cyclator tank in an estimated volume of 8000 gal. It goes to a sludge well from which it will be lifted by one of two float-controlled sludge pumps to a blending tank. Completely neutralized spent acids are periodically pumped from their treatment tanks to a neutralized acid storage tank located adjacent to the blending tank. The neutralized acids will then be pumped to the blending tank in a ratio of approximately two parts of copper hydroxide sludge to one part of neutralized acids.

Simultaneously, about 3% by weight of fly ash is added to this mixture. Contents are thoroughly mixed for 10 min. and then allowed to settle overnight. The following morning the supernatant liquor is decanted off to the metal-bearing waste tank and the concentrated sludge pumped to a concentrated sludge tank. The conditioned sludge is pumped to rotary-type vacuum filters where the moisture content of the sludge is reduced to approximately 55%; the dry sludge is trucked away for use as fill.

Treatment of Chromium Wastes With SO_2 — Hexavalent chromium occurs in wastes

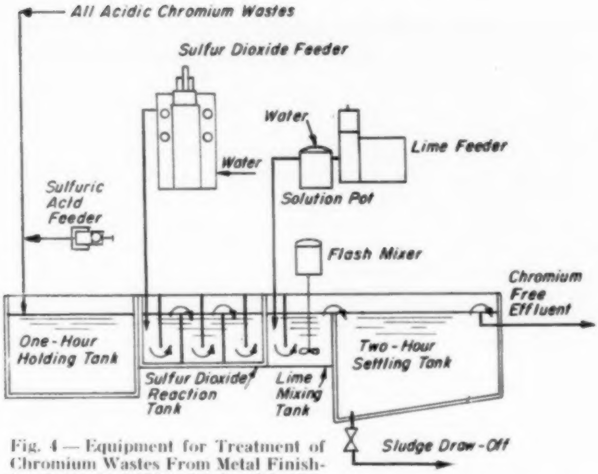
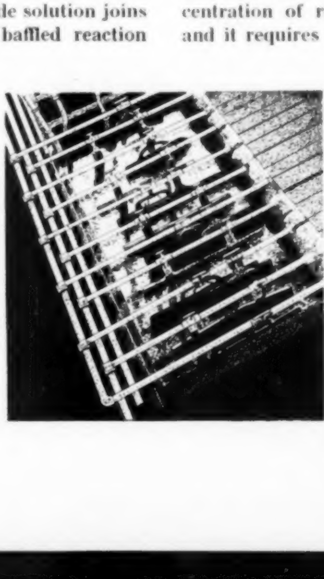


Fig. 4 — Equipment for Treatment of Chromium Wastes From Metal Finishing Operations With Sulphur Dioxide. (Courtesy Wallace & Tiernan Co.)

from the metal finishing industry where chromic acid is used for chemical cleaning, electroplating and anodizing. Reduction of hexavalent chromium with sulphur dioxide is a practical method for disposal. At a pH of 2.0 to 2.5, reduction takes place to the trivalent state. The trivalent chromium is removed as insoluble chromium hydroxide by precipitation with caustic or lime.

Figure 4 shows a chromium waste treatment setup recommended by Wallace and Tiernan Co., based on the above principles. The acidic chromium rinse waters, or other wastes, flow to a holding tank to smooth out the concentration. If the waste is not sufficiently acid, sulphuric acid is added to the holding tank. Sulphur dioxide solution joins the waste as it enters the baffled reaction tank in sufficient amount to decolorize the liquid. The pH is then adjusted by lime in a small rapid mixing tank to provide precipitation of the trivalent chromium hydroxide. Precipitation occurs in the settling tank, with the chromium-free effluent going to the sewer. The trivalent chromium hydroxide is occasionally drawn off as a sludge.



Ion exchange resins are offering a new method

Use of Ion Exchange

for treatment of chromic acid solutions. Chromic acid anodizing baths for aluminum, copper stripping baths, as well as other chromic acid baths that have been rendered useless by the accumulation of dissolved metals, such as aluminum, copper and iron, may be regenerated by passing through a cation exchange resin. The resin removes the metal ions by exchange with hydrogen ions, thus making the solution suitable for re-use. This minimizes the waste disposal problem ordinarily involved in handling these solutions. This method has proved most useful in the cleaning of solutions used for anodizing aluminum. (A thorough description of this method appeared in July 1952 *Metal Progress* under the title "Ion Exchange — A New Technique for Metallurgists".)

In many plants recovery of plating wastes costs less than their disposal. Improved means of rinsing, utilizing methods such as countercurrent washing, may be used to recover rinse waters almost completely. A typical setup of this kind consists of four tanks in series, with water entering the last tank, so that final washing is done with the cleanest water. The countercurrent washing system has the advantages that minimum water is required for vashing, a high concentration of recovered waste is produced, and it requires relatively inexpensive equipment. For some plating baths, the recovered wastes must be concentrated by evaporation before they can be re-added to the solution. Reduction in dragout automatically reduces the amount of waste to be recovered. Thus, work removed from a plating bath should be allowed to drain back into the bath thoroughly unless such practice interferes with the quality of processing.

By E. Creutz, Head, Department of Physics, Carnegie Institute of Technology
and D. Gurinsky, Head, Division of Metallurgy, Brookhaven National Laboratory*

Fabrication of Beryllium Metal

Beryllium was of early interest to the nuclear physicist working on the fission chain reaction for several reasons. It has an extremely low capture property for the thermal neutrons which produce the fission of uranium. Being of rather small atomic weight, it is useful as a medium for slowing down the fast neutrons from fission (neutrons having energies of about one to two million electron volts) to thermal energy (about 1/40 electron volt), at which energy level they have a large probability of producing fission in uranium. Elements of greater atomic weight simply scatter off the neutrons without taking up much of their energy. Also beryllium is of interest because of its rather good resistance to corrosion.

Unfortunately, very little was known about the fabrication possibilities of beryllium in 1944. Casting techniques had been developed by the Brush Beryllium Co. and others, but attempts at forging and extruding had not been very successful because of its poor ductility.

Extrusion — The first successful attempt to extrude beryllium took place at the Wolverine Tube Div., Calumet and Hecla Copper Co., in May 1944, with the cooperation of J. F. Schumar and J. F. Rodgers. Since it was believed that failure on previous attempts might have been due to insufficient pressure, a special container and die were made to take a 1-in. diameter billet on which the full 600-ton force of the press could be applied if necessary.

The beryllium billets were enclosed in covered graphite crucibles and heated in an air-filled furnace. After heating to 1900° F. for as long as 10 hr., little change in the beryllium surface took place other than some small yellow spots indicating very slight carbide formation. Immediately before extrusion, the container was lined with a magnesium cup which was to melt and serve as lubrication, since beryllium does not alloy readily with magnesium. By this technique rods were successfully extruded down to ½ in. diameter. It was found that a thin liner of graphite was at least as satisfactory as the magnesium. This broke up during extrusion but served to keep the beryllium from alloying with the steel of the die and container.

Pressure required for a nominal reduction in area (about 16 times) was about 60,000 psi. for a billet of 4½ in. diameter sheathed in $\frac{1}{16}$ in. of graphite. Higher pressures were required with smaller containers and smaller billets. Best results were obtained with the billet temperature in excess of 1995° F. although temperatures down to 1650° F. were used.

The good lubricating properties of the graphite liner are shown by the excellent flow properties of the beryllium billets. Figure 1 shows that the flow lines start almost perpendicularly from the container wall (billet surface), indicating relatively small surface friction. This condition exists to some extent even inside the die, provided that the included angle of the die is not too large. This does not happen, however, in a flat die nor one in which the included angle is as large as 160°.

A result of poor lubrication, and probably also of too high billet temperature, is the rattlesnake effect on a billet that was extruded at 2055° F., Fig. 2. Since the metal for the billet was not pure (it may have contained as much as 0.1% aluminum), hot shortness was to be expected.

Tubing was extruded using drilled billets. Several 1-in. i.d. tubes were made without damage to the mandrel, but a ⅞-in. mandrel was pulled in two. However, this fact does not necessarily indicate a limitation on the size of tube which can be extruded. A lower billet temperature could probably be used with sufficient pressure, which would result in less weakening of the mandrel.

A bell-mouth die appears desirable for good extrusion of beryllium. If the included angle is too large (120°), there is a tendency

*This work was carried out while the authors were members of the Metallurgical Laboratory, University of Chicago, operating under the Manhattan Project.

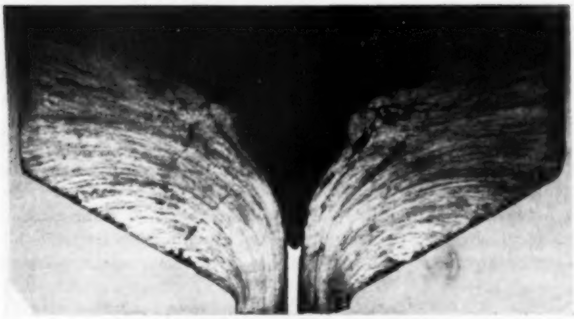


Fig. 1 — Unextruded End of Beryllium Billet Showing Flow Lines That Meet Container Wall Almost Perpendicularly

for the rod to be pulled apart and split longitudinally. The large radial compressive force supplied by an included angle of 90° or less gives better results. However, with high temperature and hot dies, good results have been obtained, even with the 120° dies.

The combination of high temperature and high pressure required poses a real die problem; nothing better could be found than 18-4-1 high speed steel treated for maximum toughness and hardness. With proper lubrication and by extruding the billet while in a thin graphite jacket, abrasion of the die is less than with uranium and other difficult materials. A problem is the occasional cracking of the hard die.

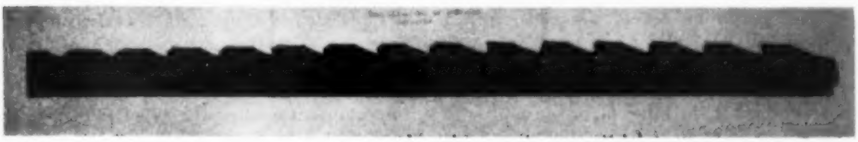
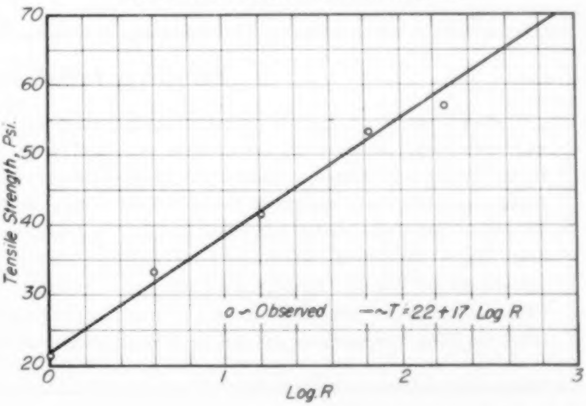


Fig. 2 — Rattlesnake Effect in Extruded Rod

As the reduction in area during extrusion is increased, both the yield point and tensile strength of beryllium are increased. This may be seen in Fig. 3 where the average ultimate tensile strength of several samples is plotted as a function of twice the logarithm to base 10 of the ratio of the billet diameter to the diameter of the extruded rod. The last point at 512 times reduction corresponds to a double extrusion — that is, a 4½-in. billet was extruded to 2 in. and then to $\frac{3}{16}$ in. Tubes extruded with small area reductions (2 to 3 times) tend to split longitudinally while cooling. Tubes are satisfactorily extruded if the billet is provided with a hole, and the reduction is 8 or more times. Cans may be made by impact extruding around a mandrel. Here also, if the reduction is small, cracking may occur.

Fig. 3 — Ultimate Tensile Strength of Beryllium as a Function of the Logarithm to the Base 10 of the Ratio of the Billet Area to the Area of the Extruded Rod



Beryllium containing 1% titanium or 3% aluminum can be extruded under similar conditions. The 3% aluminum alloy has a greater tendency to give poor surfaces than the pure metal or the titanium alloy.

Forging — In order to improve the structure of cast beryllium and thus improve physical properties such as malleability and ductility, experiments were performed on the

Forging of Beryllium

forging of beryllium at Westinghouse Electric Corp., Bloomfield, N. J. Three centrifugally cast billets 2 in. diameter and 4 in. long were enclosed in soft steel jackets ½ in. thick. Inasmuch as previous experiments showed that above 1920° F. a molten alloy is formed if iron is in contact with beryllium, a layer of calcium oxide was tamped between the jacket and the beryllium, and a steel cover was welded to the jacket to completely confine the billet. Three billets were also prepared in a similar manner except that no cover was put on the steel jacket; some unjacketed beryllium billets were also forged in these tests.

Results of the experiments indicate that with an unjacketed billet, the best product was obtained if the billet before forging was somewhere between 2100 and 2190° F. and the billet was forged with one stroke. Repeated blows resulted in a number of radial cracks starting from the outer edge and working inward. Too low a temperature resulted in complete cracking of the billet. The totally confined samples (Fig. 4) were heated to 1920° F. and forged radially under a number of strokes; reheating was necessary to maintain the desired temperature. The partially confined steel-jacketed samples were forged longitudinally.

Welding — Attempts to weld beryllium by means of the atomic-hydrogen arc and flux, the argon-shielded a.c. arc, and the helium-shielded d.c. arc have been unsuccessful. Straight polarity (tungsten electrode being negative) as well as reverse polarity helium and argon-arc welding methods are successful.

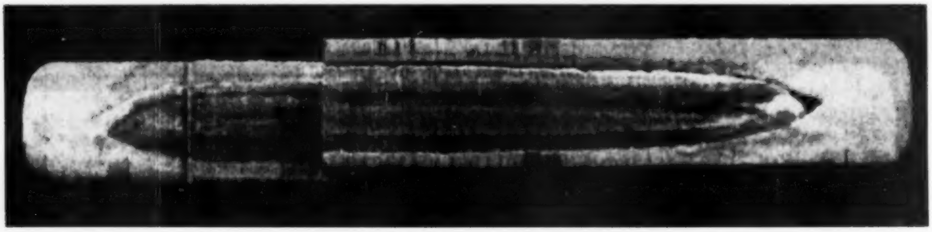


Fig. 4 — Beryllium Billet Encased in Steel and Forged

Conclusion — It has been found possible to fabricate beryllium metal by extrusion and forging. With the first method it is useful to jacket and lubricate the billet with a thin shell of graphite, and with the second, it is important to confine the billet with a mild steel jacket to prevent edge cracking. Mechanical properties — in particular ultimate tensile strength — are appreciably improved over those available in cast beryllium after treatment by either of these fabrication methods.

Beryllium Poisoning

Beryllium and some of its compounds are extremely toxic when taken into the lungs or blood stream. This toxicity is highly specific, varying greatly with individuals. Several deaths traceable to the handling of beryllium metal powder and powdered beryllium compounds have occurred during the past few years. Therefore, extreme precautions should be taken in handling any of these, particularly in carrying out operations where dust or fumes are generated. Handling of the metal with gloves or machining only under adequate fluid lubrication and with the operator wearing a respirator are highly recommended. The effects of beryllium poisoning frequently do not become apparent until several years after exposure.

By John K. McIver, Commercial Controls Corp., Rochester, N. Y.

Salt Bath Carburizing

MANY OF THOSE who are concerned with heat treating may have at some time wondered whether gas, pack, or salt bath carburizing was the best way to case harden a certain product. The question usually comes up when some part fails to hold shape or to carburize as it should. Perhaps even a few wistful thoughts might have come to mind, like: "What a cinch this job would be if we could gas carburize," or "In a salt bath, this job would be a pushover."

Salt bath carburizing does have many advantages. Capital investment for original equipment is relatively low. Operating costs are within reason. Large volumes and a great variety of work can be handled through the same piece of equipment. Various results can be obtained to suit the entire range of case carburizing requirements.

Our firm, a medium-sized plant manufacturing diversified products, has depended on salt baths for almost all case hardening work. Specifications are met regularly for case depths which cover the range from 0.0005 to 0.060 in. minimum. The steels that are treated vary from A.I.S.I. B1113 and C1010, all the low-alloy carburizing grades, all carburized die steels, and even occasionally to an emergency job of restoring carbon to the surface of high-carbon steels. Production orders may be as low as 25 pieces of a kind, and have run as high as 500,000. Smallest parts run 830 to the ounce, and the largest are stampings weighing several pounds. We have found salt bath carburizing to be more adaptable to this range of work than any other method.

Case Depth — Control of case depth is an important factor. Figures 1 and 2 show in a general way what may be expected for various treating times at different temperatures. Suppose that 0.093-in. plates of C1010 require a case depth of 0.0005 to 0.001 in. Figure 1 shows that 5 min. at 1450° F. will give just a little less than 0.001-in. case. If a shallower case is preferred, either the time can be reduced to 4 min., or the temperature can be reduced to 1425° F. Suppose a shaft of C1020 is to have a case of 0.015 to 0.020 in. after grinding, with 0.010 in. being allowed for removal after heat treating. To get the 0.025 to 0.030-in. case needed before grinding, Fig. 2 shows that the shafts can be carburized for 2 hr. at 1650° F. or for 4 hr. at 1550° F. The case will be the same with either treatment, but case and core properties may be affected by quenching temperatures. With C1117 the toughest core and most refined case will be obtained by oil quenching from 1625 to 1650° F., reheating to 1425° F. for 4 or 5 min. in salt, again quenching in oil followed by a final temper at low temperature.

Heating Time — Since heat transfer from a liquid to a solid is quite rapid, and since the heat content of a salt bath is high due to the weight of salt and pot, work comes to carburizing temperature quickly and with only a small loss of furnace temperature under normal operating conditions. This means that only small allowance has to be made for heating time, and usually the total time in the salt and time at temperature for pieces of small and medium size not tightly packed can be considered the same. Small parts that are tightly packed, such as screws and rivets run in baskets, are the exception to this practice because the center of the load is much slower to heat than the surface. This is especially true with heating times of 10 min. and under if care is not paid to the size of load; the surface pieces will be up to specification whereas those in the center will have almost no case — in fact, may not have reached temperature. However, by using care in racking so the parts will heat uniformly, by being sure all parts in a run are from the same heat of steel, and by using charts as in the examples above, extremely close case depth tolerances can be maintained.

When carburizing assemblies are made of different grades of steel, different depths of case will appear on the various parts. This is true with any method of carburizing, and makes it necessary when working to close depth limits to have a decision on what part is most important. For example, where a B1113 pin is brazed into a C1020 arm, is the pin of B1113 the controlling factor or is it the arm of faster carburizing C1020?

After Copper Brazing — The subject of assemblies brings up another point in favor of salt bath carburizing. If the plant does copper brazing, it may have had jobs on which the copper ran over the areas to be

hardened. Because copper is a carburizing stop-off it has to be removed. The copper-stripping process is not always perfect and occasionally traces of copper may remain. In gas or pack carburizing this would be enough to leave soft spots, but by using cyanide-base salt baths, soft spots from this cause are greatly reduced. This is because cyanide dissolves copper; therefore, any thin film of residual copper is removed in the early part of the process.

In Silver Brazing — Cyanide-base carburizing baths can also be used as the heating medium for silver soldering of assemblies. Wire rings of silver solder are placed around the joints to be soldered and the assembly put into the pot. No preliminary fluxing is necessary, as the salt is a flux. As soon as the parts come to heat, the solder flows as it would with conventional practice. Needless to say, if these are steel parts they will have picked up some carburized case. For that matter, the assemblies can be left in as long as necessary for the desired depth of case.

Handling — Salt baths can handle a wide variety of sizes and shapes of parts, and all kinds of hooks, fixtures and baskets can be used to hold the parts in position during carburizing without any height limitations caused by entrance doors and cover. Exhaust equipment can be designed not to interfere with overhead handling. Because any part of the holding fixture above salt level is relatively cool, heat resisting alloys are needed only for the parts in the salt. This has considerable bearing on the cost of heat treating fixtures and, in these days of nickel shortage, helps the available nickel go further.

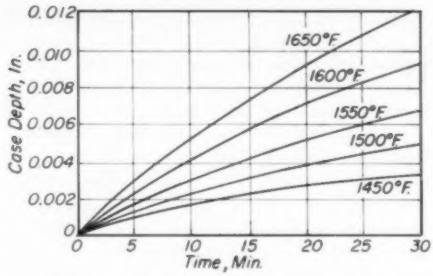
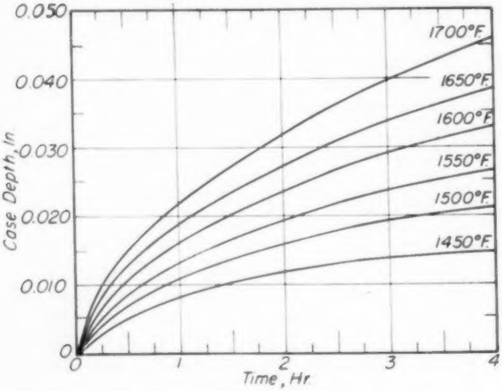


Fig. 1 — Depth of Case Measured on Fractured A.I.S.I. C1010 Test Pieces 0.040 In. Thick, Brine Quenched After Carburizing at Temperatures Indicated

Fig. 2 — Depth of Case Measured on Fractured A.I.S.I. C1020 Test Bars Brine Quenched From Indicated Carburizing Temperatures



Composition of Case — The case composition can be controlled over fairly wide limits by control of bath composition and temperature. Most case hardening baths contain cyanides, and all cyanides under operating conditions have a carburizing action and a nitriding action. At low temperature, nitriding predominates and cyanide-base baths are used at about 1000° F. for putting a nitride case on hardened high speed steels. At the other extreme are the activated deep case carburizing mixtures that give a case of almost pure carbon and with little if any nitrogen. In addition to control over the carbide-nitride mixture ratio, a fairly broad range of carbon content is possible in the surface of the case.

When a properly catalyzed hardening bath is used according to the manufacturer's directions, the case put in at high temperature will be higher in carbon content than at a lower temperature. The range of carbon content just under the surface is from a high of about 1.20 to about 0.70% in a case obtained at 1400° F. There is another way (a little more difficult to control) in which lower carbon of any case depth can be obtained. This is to operate the bath with a lower cyanide content than recommended. For instance, 2 hr. at 1550° F. in a normal bath will give a 0.020-in. case with 0.90% carbon near the surface (Fig. 2 and 3). By allowing the cyanide content to drop to about half the recommended minimum, it is possible to get a 0.015-in. case having 0.50 to 0.60% carbon at the surface. These deep low-carbon cases are very useful in a few applications because they are less subject to cracking. It should

be recognized, however, that these do not have the wear resistance of a high-carbon case. The same effect can, of course, be developed by using a normal case, then holding the part at carburizing temperature in a neutral atmosphere and allowing the surface carbon to diffuse into the piece. Carbon recovery in the surface of decarburized higher carbon steels has been done by us using both methods. The first method is perhaps the best, but it does involve considerable loss of productive time to unbalance the chemistry of the carburizing bath and then to build it to normal for the regular work.

Selective Hardening — Salt baths are also very useful for partial or local hardening.

Masking of areas where case is not wanted by use of copper plate or stop-off paints works as well with salt baths as it does with gas or pack carburizing. (This is not contradicting the previous statement about removing *traces* of copper left after copper brazing. The cyanide-base baths do remove copper. It is necessary to apply enough thickness to withstand the time of attack.) Often a 0.0005-in. thick plate is enough. It is also possible on most grades of steel to air cool after carburizing and to remove case from unwanted areas by machining. The whole piece is then heated in a neutral medium and quenched. Only the areas with case remaining will be hard. Still another way is to carburize, air cool, and reheat for quenching only those areas which are to be hard. This method will, of course, give a high-carbon case, even on the unhardened areas. All these methods of local hardening will work with any method of carburizing. One way to get local case hardening that is peculiar to salt baths is to immerse only the section of the piece to be hardened. As this requires no masking of areas to be without case, where case is not desired, and since the pieces can be quenched from the carburizing heat, this is by far the cheapest way to do local carburizing.

Economy — Because the cost of equipment depends on its size, method of heating, type of temperature control, and such factors, its dollar value is variable. It can be stated, though, that of two pieces of equipment to do the same carburizing job, the salt bath is almost always considerably cheaper. Operating costs on a per-piece or per-pound basis are also subject to great variation, depending on how heavily the equipment can be loaded, amount of salt dragout, ratio of productive hours to total hours of operation, maintenance and repair costs, and so on. But over the life of the equipment it is usually as low as any method of carburizing.

We have found that, taking everything into account — variety of results required, variety and quantities of parts processed, and costs — salt baths are the only practical way for us to do our case hardening.

Acknowledgments — The data for Fig. 2 and 3 are taken from information published by the American Cyanamid Co. for its carburizing salts.

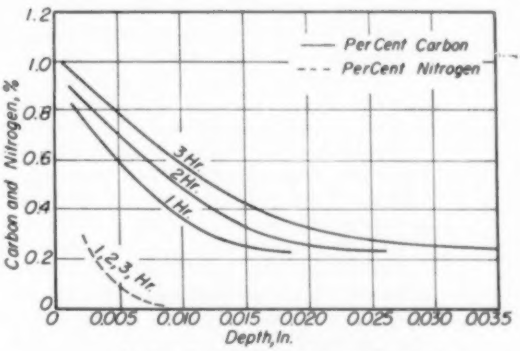


Fig. 3 — Carbon and Nitrogen Gradients Taken From A.I.S.I. C1020 Test Bars Carburized at 1550° F. and Cooled Slowly

By Anton deS. Brasunas, Metallurgist, Oak Ridge National Laboratory, Oak Ridge, Tenn.*

Subsurface Porosity Developed in Sound Metal During High-Temperature Corrosion

SUBSURFACE voids have been observed in Inconel and similar alloys during processes involving the depletion of chromium by any of the following methods: *(a)* leaching with certain molten salts; *(b)* high-temperature vacuum treatment; *(c)* high-temperature oxidation.

Porosity in metals had been observed previously and noted in the literature relating to metallic diffusion phenomena; it has been attributed to the uneven diffusion rates of atoms of different metals through a crystalline space lattice. Although similar observations have not previously been reported in corrosion studies, their occurrence should not be too surprising. However, voids have been reported in oxide layers, where metal ions are known to diffuse more rapidly through the oxide lattice than oxygen ions.

Alloys are known to change in composition in the surface regions because of the higher reactivity of certain constituents at the metal interface. Such depletion without adequate replacement of removed atoms causes vacancies, which may "precipitate" or accumulate to form visible voids. Although undesirable, this newly recognized form of corrosion is not as damaging as some others, and could be tolerated in certain instances.

Corrosion in Molten Fluoride Salts — Corrosion tests, in which fused alkali metal fluoride salts come into static contact with chromium-bearing alloys such as Inconel (75% ~~Ni min.,~~ 15% Cr, 10% Fe max.) at temperatures above 1300° F., have resulted in porosity in the surface layer several mils deep, as illustrated in Fig. 1. Although it is fully recognized that voids have been often observed under the microscope because particles have been physically removed during polishing, certain phases may have reacted with water and dissolved, or etch pits have formed during preparation of the sample, it seemed nevertheless possible that these pits (Fig. 1) may be true voids as suggested early in this program of corrosion research by W. D. Manly and N. J. Grant. Careful polishing using nonaqueous techniques failed to show any difference in the appearance of the porous surface of the metal in the etched or unetched conditions. Chemical analyses of the metal surface before and after testing have indicated only one significant change: There was a drop in the chromium content to about 5% (originally it was about 15%). The analysis of the fluoride salt used as a corroding bath showed a correspondingly higher chromium-to-iron and chromium-to-nickel ratio than one would obtain by uniform attack of the alloy, thereby clearly establishing the selective removal of chromium.

SUPPLEMENTARY DATA

Saturation of the fluoride salt with chromium prior to testing prevented this formation of voids in tests which would otherwise develop voids to a depth of several mils. Furthermore, the measured area of the voids in such samples as Fig. 1 agrees very closely with the loss in chromium as calculated on the basis of the change in analysis of the metal at the surface, mentioned above. This computation assumes no over-all volume change of the specimen.

If voids are caused by chromium depletion, as these experiments indicate, then they should also be observed when chromium is lost through other means. Therefore, two methods were tried; the first technique involved high-temperature vacuum treatment and the second involved high-temperature oxidation. Both attempts were successful and will be described briefly.

High-Temperature Vacuum Treatment — The high vapor pressure of chromium, relative to that of iron or nickel, suggests that

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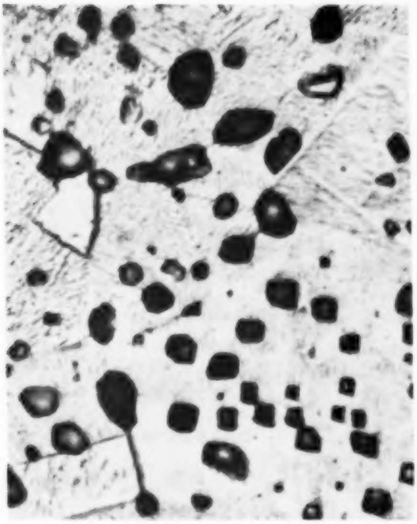


Fig. 1 — Appearance of Subsurface Voids in Inconel at High Magnification. Etched, 2000 ×

high-temperature vacuum treatment would produce a sizable chromium gradient. Inconel and 80-20 Ni-Cr alloy were therefore exposed to a vacuum of 0.1 mm. Hg for 42 hr. at 1375° C. (2500° F.) and then furnace cooled. Chemical analysis of the entire Inconel specimen indicated an appreciable drop in the chromium content — from 14% to 8%. Both samples showed many subsurface voids; those in Inconel appeared to be spherical, whereas those in the 80-20 alloy were angular. The latter are shown in Fig. 2.

High-Temperature Oxidation — It is well known that chromium-bearing alloys have good high-temperature oxidation resistance which can be attributed to the formation of a chromium-rich and diffusion resistant oxide phase on the surface. The chromium in the oxide phase is supplied by the surface itself and the underlying regions of the metallic specimen. This would tend to deplete the subsurface layers in chromium.

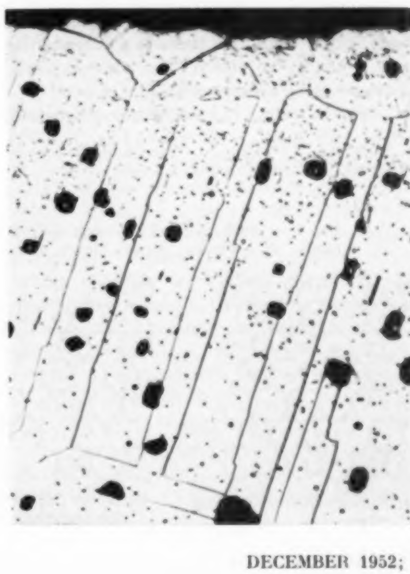
An Inconel specimen was therefore exposed to air at 1250° C. (2280° F.) for 200 hr. After oxidation, metallographic examination revealed the usual oxide layer on the surface and oxide penetrating the adjacent grain boundaries for a short distance. In addition, much deeper subsurface voids were observed, as anticipated, and these are shown in Fig. 3 on the following page.

Theoretical Considerations

The tests just described strongly indicate that voids are formed by chromium depletion. The formation of cavities large enough to be resolved by an ordinary microscope is visualized to occur as is illustrated schematically in Fig. 4. As chromium atoms are taken away from the surface of the metal by leaching, evaporation or oxidation, a concentration (activity) gradient results which causes chromium atoms from the underlying region to diffuse toward the surface, leaving behind a zone enriched with vacancies, somewhat as shown in the center sketch of Fig. 4. These vacancies can later agglomerate at suitable sites and appear as voids (right-hand sketch).

It is generally accepted by physical metallurgists that metal crystal lattices are not absolutely perfect in their geometric arrangements, and that vacancies exist in the lattice structures of solid metals. The amount that can be tolerated increases with increasing temperature. Furthermore, vacancies can also be generated at surfaces, grain boundaries, inclusions, dislocations, and other defects. Diffusion is therefore visualized as taking place principally by the movement of vacancies; that is, neighboring atoms move

Fig. 2 — Section of 80-20 Ni-Cr Alloy After 42-Hr. Exposure to Vacuum at 1375° C.; Void Shape Bears Some Relationship to Twin Lines; Note Similarity to Fig. 1. Etched, 250 ×



Mechanism of Void Formation

to occupy vacant sites. This gives the illusion that the vacancy itself is moving in the opposite direction.

For the sake of clarity none of the existing "tolerated" vacancies are shown at the left of Fig. 4, although they must be assumed to be present at all times. The left sketch shows the nickel, chromium and iron atoms arranged at random as one may expect to find them on the (111) plane of a crystal in Inconel. After selective diffusion of chromium has occurred by any of the methods described (from about 15 down to 5%), vacancies must result if these vacant lattice sites are not filled by nickel or iron atoms diffusing inward from the surface proper. If the lattice had been "saturated" with vacancies at the beginning, then these additional ones are not tolerated and must "precipitate", as shown in the sketch at right in Fig. 4. For ease of illustration, only six atoms are shown to have precipitated to form a void; the number of missing atoms in voids observed in these experiments is of the order of a trillion (10^{12} atoms).

It will be noted that the voids shown in Fig. 2 are of two sizes. The larger ones are believed to have occurred at temperature in the manner described, whereas the smaller ones may have been produced on cooling. Rough approximations of vacancy densities at several temperatures based on the formula of Mott and Gurney* indicate that such a theory is not impossible. Hence, one may justifiably assume that there is a temperature coefficient of "solubility" for vacant atoms (as there is for foreign atoms).

Conclusions — In reactions where the net effect of the diffusion involved is essentially mono-directional, there is a movement of mass that results in a change in density or shape of that portion of the specimen (or both). If the concentration of vacancies left behind is greater than some critical value, they will tend to collect at suitable locations and appear as visible voids. Such diffusion phenomena have been observed on a number of occasions when bimetallic (that is, metal-metal) diffusion couples were studied. The experiments described in this paper indicate that identical effects can be obtained in metal-liquid and metal-gas systems where similar diffusion phenomena occur.

*N. F. Mott and R. W. Gurney, "Electronic Processes in Ionic Crystals", Oxford Clarendon Press, 1940, p. 31.

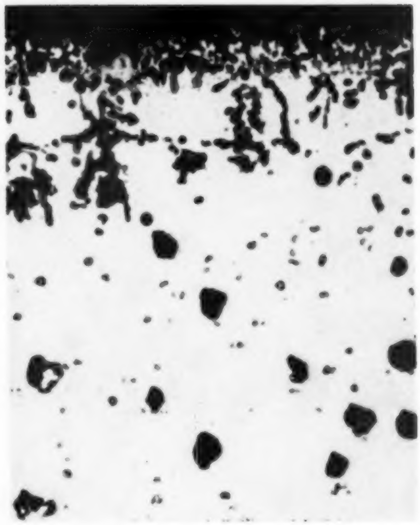
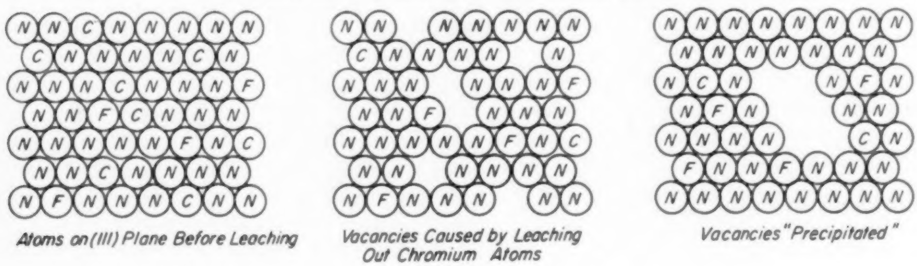


Fig. 3 — Section of Inconel Specimen After 200-Hr. Exposure to Air at 1250° C. Note void formation beneath oxidized region. Unetched, 250 ×

Fig. 4 — Mechanism of Subsurface Void Formation Showing Vacancy Movement. N indicates nickel atoms, C chromium atoms, and F iron atoms



Quality Considerations for Bronze Castings*

By **Harold J. Roast,** Consulting Editor to Metal Progress

The architect or engineer, chemical or mechanical, is interested in any improvement of materials. Only as the engineer has confidence in the product is he justified in using bronze castings.

Many improvements have been made in the past 20 years (and especially during the past five) in various aspects of the manufacture of bronze castings.

The engineer himself has acquired a more definite knowledge of what strengths and other physical characteristics he needs in the construction of the many units required in the modern manufacturing plant. Special corrosion problems arise in the ever-expanding oil fields and refineries and the machinery connected therewith. Castings that may suit many other purposes require to be made from special alloys. Every art and every mechanical product has its limitations and, while anything that raises the standard of quality is to be commended, there must be an agreed-upon standard between the user and the producer for materials that are capable of manufacture and of production at a price commensurate with the needs.

In the good old days, England, and Europe generally, had guilds that were formed by groups of artisans of the various trades; bronze founding was no exception. These guilds did much for the development of the crafts, especially in creating a more-or-less steady succession of apprentices.

During the past 50 years, associations, societies and institutes have come into being whose object is to improve the standard of manufactured products. Some are purely scientific groups engaged in metal research, both pure and applied, and its discussion and publication, while others put the emphasis on the application of the latest scientific information to manufacture. Still others are confined to drawing up specifications for the guidance of engineers, foundrymen and ingot-producing smelters, although even here it is recognized that a generous accumulation of proven facts must underlie any sound specification.

The result of these combined efforts is a greatly improved bronze casting — improved not only as to quality but uniformity, within the piece and piece to piece.

Concurrently there have, of course, been improvements in such fields as rolling of bronze sheet, drawing of wire, welding and forging — as well as various competing metals and alloys.

On account of the troubles that the engineer has had in the past with castings, he gradually favored mechanical assemblies of articles, because the work done on the metal during the process of fabrication eliminated badly defective metal automatically and generally produced bars, flats, sheets and shapes less likely to have such defects as subsurface holes, which were exposed on machining, and weaknesses associated with undiscovered ones. However, there are many instances where a cast product has an inherent superiority over the fabricated. Particularly is this so where the resistance to corrosion is a prime factor. One of the chief causes of corrosion is electrolysis, and recent painstaking research has shown that very definite differences of potential can be set up in an electrolyte by a variation in the amount of cold and hot work as between various pieces made of the same alloy in any given assembly.

Properly made bronze castings have the greatest homogeneity of any metallurgical product; as a result they should have a distinct appeal to the chemical engineer. The object of the foundry is to supply bronze castings honestly good all the way through. When this is done the engineer will find an increasing number of applications where bronze castings are to be preferred to any other form. Again, conditions arise where an alloy that cannot be fabricated by rolling, welding or stamping is the one that will give the best results under the conditions of use. In such conditions there is only one method to be used — namely, casting.

*Taken from Chapter XV "The Engineer's Viewpoint" of Mr. Roast's forthcoming book on "Bronze Castings" to be published by the American Society for Metals early next year.

Progress in the Bronze Foundry

Among the many improvements that have been introduced to the bronze foundry, none are more important than the speed-up in melting the metal. It is agreed that the longer metal is held in the molten condition the greater the danger of deterioration. Originally wood and charcoal were the only fuels available, and the furnace was placed atop a hill to use the prevailing wind for forced draft. The modern foundryman has oil, city gas, natural gas and electricity at his disposal and excellent furnaces for each. Not long ago the melting of 200 lb. of bronze would take from 1½ to 2 hr.; it is now 20 min. This definitely reduces the damaging effect resulting from long exposure to atmospheric attack.

It has also been found that temperature plays a very important part in the making of a good casting. As recently as 1910, a well-known metal journal published a statement by an outstanding metallurgist that "there is no pyrometer on the market that can be used in routine brass foundry work with success". Today we can take temperatures of molten bronze with very little trouble and to an accuracy, in the ordinary foundry routine, of 20° F. — even to 10° F. if a little extra care is used.

The nature of the furnace gases used to be considered a matter of no moment, whether oxidizing or reducing. The result of the careful work of a number of scientifically minded observers has been to prove that an oxidizing atmosphere is definitely superior to a reducing atmosphere. This removes another of the hazards of casting production. The advent of electric induction furnaces, either of high or low frequency, is perhaps one of the greatest advances in modern metallurgy, for they provide speed of melting, control of atmosphere and adequate mixing — the three main essentials of successful melting.

Improvements in molding have also been made. The sands used for static molding have been immensely improved; sand controls have been standardized, which makes for uniformity of mold material.

The introduction of centrifugal and of continuous casting has also improved the means of production. The purchasing engineer does not have to be expert in the details of molding and casting but it is of interest to him to know what progress has been made that will redound to his advantage.

Again, methods of testing have been greatly refined. Especially is this true of nondestructive testing such as X-ray, gamma ray and sonic testing, whereby the satisfactory condition of the casting through and through can be shown without interfering with its subsequent use.

In the field of chemical analysis we have the fast and accurate spectrographic units, not to mention the replacement of color indicator tests by those based on differences of electric potential.

The field of architectural uses has not been neglected. The revival of the lost-wax process enables the foundry to supply bronze castings of the highest order of beauty, both of color and form. There is something about the warm color of bronze that appeals to us, possibly an atavistic reaction from the Bronze Age. Permanence and dignity are associated with bronze — hence its use for statues, decorative bronze doors, and grilles and ornamentation in our halls of finance. Ingot metal for these alloys also is quite satisfactorily made from reclaimed metal, properly refined by the smelters, and thus a paucity of supply is avoided.

And now, what of the future for bronze castings?

The designing engineer, whether architectural, chemical or mechanical, may rest assured that the metallurgist, ingot maker and foundryman will keep pace with all reasonable requirements. He may with confidence rely upon cast bronze in increasing measure as fancy or utility may dictate.

Cast Silicon Bronze Bells — a Modern Example of an Ancient Foundry Art

By Victor Paschkis, Technical Director

Heat and Mass Flow Analyzer Laboratory, Columbia University, New York City

A Cooperative Research Program on Quenching

This paper will describe in general terms a research project on quenching now under way at Columbia University. It will give its background, purpose and organization without being a progress report on results obtained or the equipment used.

First as to the formulation of the problem. It is customary to speak and think of quenching as a unit operation. Under this all-embracing concept, a number of individual problems occur, through the solution of which (and perhaps *only* through the solution of which) progress can be achieved. Since the project to be described deals with only one of these problems, it may be well to list the others briefly in logical sequence.

Limiting our attention to the iron-carbon alloy steel, the purpose of heat treating — including quenching and tempering — is to obtain a desired distribution of mechanical properties in the part.

The purpose of quenching, an early step in the operation, is to achieve a certain distribution of martensite in the piece.

The distribution of martensite — or, more generally, the geographic distribution of structure in the piece — depends on the rates of temperature change, particularly at certain temperatures or within certain ranges.

It should be noted, however, that the rates of temperature change are not the same in different parts of the piece; they also change with time. One might therefore speak of "a geographic distribution of rate-histories"!

The rate of temperature change, finally, is influenced by size and shape of the piece, and its properties by the nature and agitation of the quenching medium.

So much for the statement of the problem in generalized terms. What is our present background of accurate information? The relationships between hardness and structure are qualitatively understood. The relationships between structure and rate of temperature change are known in a general way. Although more information in these two fields is desirable, they are sufficiently understood to permit their control. But the relationships between rate of temperature change and nature of the piece and of the quenching medium are understood only vaguely and empirically. The main unknown here is *boundary conductance*, discussed in detail below. In other words, if it is desired to get a certain rate of temperature change at a given point in a piece, only an empirical approach is possible today, which frequently is costly in time as well as materials. The present research program deals entirely with the last-mentioned problem — rate of temperature change, as governed by the several variables of material and quenching medium.

Let us now consider the "rate of temperature change". (This term has been used above with reference to the piece to be hardened.) Rate not only changes with time, but also with distance from the surface. When cooling a piece that has been heated to a uniform temperature, rates of temperature change first increase rapidly; after reaching a peak they decrease, first quickly, later more slowly. For any given piece, fastest rate is at the surface, and it decreases with increasing distance from the surface. In addition, a time lag occurs — rates in the center may increase at a time when those at the surface have passed their peak and are already in the decreasing phase. Figure 1 shows one example, and applies to a 4-in. plate; rates of temperature change are plotted against time after start of cooling. The curves are drawn for certain simplifying assumptions which are not important here; they do show clearly the time lag between the rates at the surface and in the center and the difference in maximum rates achieved.

The factors influencing rate of temperature change can be arranged in three groups:

1. Factors connected with the piece: distance from the surface; shape; size; surface condition (clean or scaled, smooth or rough); thermal properties (thermal conductivity, specific heat, heat of transformation); initial temperature distribution.

2. Factors connected with the quenching

medium: properties (viscosity, thermal conductivity, density) and temperature.

3. Factors connected with both piece and quenching medium: relative position of the two (for example, a cylinder immersed parallel or perpendicular to its axis); relative velocity (for example, speed of immersion and agitation of the quenching bath).

BOUNDARY CONDUCTANCE

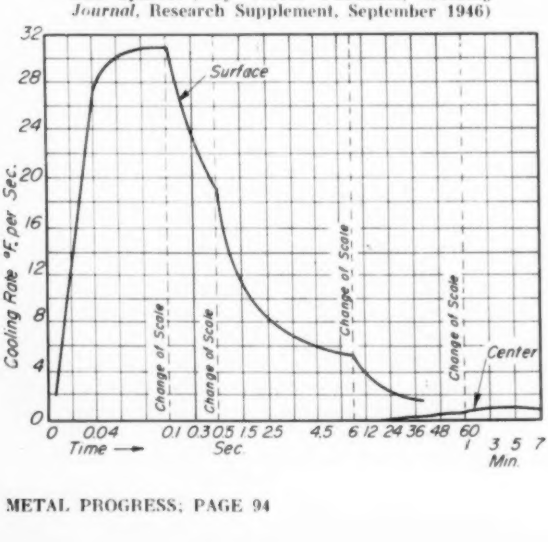
In view of the many factors involved and the almost unlimited variability in at least some of them (shape and size of the piece), how can one hope to obtain valid answers from a systematic and fundamental study, which obviously cannot pay any attention to all the actual shapes occurring in industrial practice? To answer this question it is helpful to consider the thermal aspects of quenching. It is simple to write a heat balance, stating that the loss in heat content of the steel must equal the gain of heat content of the quenching medium. But such a balance does not disclose anything regarding time and rate. Loss of heat of the piece, with the concomitant temperature drop, results only by heat flow from the surface of the piece to the quenching medium. In fact, the rate of flow at any one instant from the inside of the piece to its surface equals the rate of heat flow from the surface into the quenching medium.

These two rates of heat flow, which must at all times equal each other, can be studied separately. The rate of heat flow to the surface depends on *(a)* the initial temperature of the piece, *(b)* the thermal properties of the piece, *(c)* size and shape of the piece, and *(d)* temperature of the surface at any one instant.

We call the rate of heat flow from the surface to the quenching medium, per degree temperature difference and per unit surface area, the "boundary conductance". As stated above, this rate at all times equals the rate of heat flow in the body to the surface; the boundary conductance is therefore of determining influence on the rates of temperature change within the piece. If we can evaluate the boundary conductance accurately, we can predict the rate of temperature change at different points within the body.

The boundary conductance is influenced by several factors: *(a)* texture of the surface of the piece (roughness), presence or absence of scale, and nature of the scale; *(b)* thermal properties of the quenching medium, conductivity, specific heat, density, viscosity; *(c)* relative velocity of surface and quenching medium; *(d)* wetting ability of quenching medium; *(e)* temperature difference between surface and quenching bath; and (probably) *(f)* the past history of surface temperature. Boundary conductance is *not* influenced by the nature of the material, or shape or size of the body behind the surface. Thus, in our present study many of the variables listed above are eliminated, since it deals with boundary conductance only.

Fig. 1 — Cooling Rates at Surface and Center of 4-In. Steel Plate, Quenched From 1670° F. in Coolant at 70° F., as They Vary With Time. (From "Cooling and Heating Rates of Plates, Cylinders and Spheres", by Victor Paschkis, *Welding Journal*, Research Supplement, September 1946)



The boundary conductance is of importance in other fields of industrial endeavor — for example in design and operation of steam boilers and of oil stills. Why is further research necessary, and why can the studies in these two fields not be applied to metallurgical quenching directly? There are two significant differences between the boundary conductance prevailing in heat transfer apparatus such as boilers and stills and in quenching: First, surface temperatures in quenching are considerably higher than those in ordinary heat transfer apparatus, and second, in such apparatus steady-state conditions prevail — that is, the surface temperature does not change with time,

whereas in quenching it rapidly changes. There is reason to believe that such rapidly changing temperatures result in boundary conductances different from those obtaining in a steady state.

Although values of boundary conductance established at lower temperatures and in steady state are not directly applicable to quenching problems, it is anticipated that much information may be gained from studies in these more conventional fields.

Hoped-For Results — It is anticipated that this research program will yield two practical results of significance:

1. Upon completion, it should be possible to predict the time-temperature history, and particularly rates of temperature change, in pieces of any shape or size during quenching.
2. It should be possible to compare objectively different quenching media on the basis of boundary conductance.

Boundary conductance in quenching is not a constant, but changes with time. If these changes can be determined, then modern computational techniques enable us to predict the time-temperature history at any point within the piece, provided its thermal properties are also known (conductivity, density, specific heat and heat of transformation).

Quenching mediums can be compared today only by comparing hardness distributions in steels quenched in them. We must fill a tank with the liquid and operate it for a while, until sufficient data for comparison have accumulated for various pieces in production. Instead, it should be possible to establish boundary conductance values for each quenching medium, so that its purchase, acceptance tests, and tests of performance after a given length of service can be based on a definite item, to be expressed numerically as "boundary conductance under specified conditions".

The desired results can be obtained by studying the different variables which influence boundary conductance. For example, if boundary conductances are determined for pieces of the same shape but of a few different sizes, size relationships can be established in a more general way. However, it is hoped that our experiments will give sufficient insight into the heat transfer across the surface so we can formulate the boundary conductance values in a more basic manner.

Moreover, study of different factors in the quenching medium itself should yield some understanding of what basic properties

Fig. 2 — The Heat and Mass Flow Analyzer at Columbia University Utilizes Electrical Measurements in Appropriate Combinations of Resistances and Capacitances to Study Analogous Problems of Heat Flow in Solids

to look for in developing new quenching mediums — for example, the relative importance of wetting and viscosity should be better understood at the end of this program.

In any investigation of this kind temperature must be very accurately measured; therefore, a special study of errors is being made. This should prove helpful to instrumentation generally, quite independently of the results in the actual quenching program.

Finally, a continuation of the program may lead to a better knowledge of rates of transformation in steels.

Method of Approach — Since boundary conductance is a surface phenomenon, it would be most desirable to measure the change of surface temperature with time, and as influenced by the bulk temperature of the quenching medium. These figures would lead directly to a value for boundary conductance. Unfortunately, it is entirely impractical to measure surface temperatures, particularly if they undergo such rapid changes as in quenching. The very presence of a thermocouple, however carefully fastened, distorts the conditions of fluid flow at the surface — and boundary conductance is determined by the fluid flow. The leads of the couple also change the temperature field locally.

Therefore, temperature measurements will be carried out *within* the sample. From these time-temperature curves, obtained for several points in the body, the time-temperature history of the surface can be computed by means of the heat and mass flow analyzer at Columbia University, an analog computer described in *Metal Progress*, N vember 1947.

Experimental Quenching Procedures

The experimental procedure thus comprises two parts: first, carrying out quenching experiments, with measurement of the temperatures inside the body, and second, computation of surface temperatures and boundary conductance values from the results obtained in the experiments.

Evaluation of the data is greatly simplified if the material to be quenched undergoes no transformation. Therefore, quenching experiments will be carried out with silver samples. This is permissible, since boundary conductance is a surface phenomenon. Different degrees of surface roughness can be produced on the sample. Verification tests, comparing hardness distribution in steel samples with conclusions based on the work with silver, will then be conducted. When work with scaled surfaces begins, it will be necessary to use another material than silver.

Work will start with the simplest conditions — that is, clean surface, simple shape (sphere), and quiescent quenching medium. Four different mediums will be investigated at the beginning — brine or a similar medium, one light and one heavy oil, and water. Gradually, as experience is gained, more and more complex situations will be explored.

Experimental equipment now includes a furnace for heating the sample, equipped with thermocouples to determine the temperature distribution in the piece; a dropping mechanism to deliver the sample to the quenching bath under specified conditions; a quenching tank filled with the appropriate medium, with and without means of agitation; means for measuring the temperatures within the sample, which change quite rapidly, even at points remote from the surface.

Organizational Setup — A research project as inclusive as this cannot be anticipated in all details. Therefore, a three-year program has been outlined as the first step; this first three-year program is now under way, having been started in August 1951. It is too early to state definitely how many such programs will be required to exhaust the field, but a preliminary guess is four or five.

The program is supported by sponsors,* by Columbia University, and by the Engineering Foundation. The latter supports the program on recommendation of the American Institute of Mining and Metallurgical Engineers, and its contribution is in proportion to industrial support received.

Sponsors can be either industrial concerns, professional societies, foundations or individuals. The list is still open; in view of the fundamental nature of this research, it is desired to distribute the burden of the work over a large group, each individual sponsor contributing only a modest amount. Each sponsor subscribes for a period of three years, paying a flat rate, which is either prorated over the three years or made in one lump sum, according to his option.

Each sponsor receives monthly progress reports, dealing briefly with the work performed in the last month. When sufficient material has accumulated to warrant it, a technical report is issued. Results will be published eventually, but sponsors will be protected by an appropriate time-lag between issuance of any report and publication.

Each sponsor appoints a person as technical delegate to a "sponsors committee". The members of this committee meet several times a year, inspect the work in progress, discuss the next steps, and consult with one another so as to keep the work continuously as close as possible to practical industrial questions.

In addition to the delegates of the sponsors, this committee includes three members of the Columbia faculty who can contribute to specific problems relevant to the present research: Prof. H. D. Baker, in view of his extensive studies in thermocouple measurements; Prof. T. B. Drew, in view of his experience and studies in the field of boundary conductance, and Prof. M. Gensamer, in view of his metallurgical interest in the problems under discussion and his broad knowledge of the metallurgy of quenching.

*The following is a list of sponsoring organizations supporting the quenching research program:

Ajax Electric Co.
American Steel Foundries
Barber-Colman Co.
Bell and Gossett Co.
Bendix Products Division, Bendix Aviation Corp.
Caterpillar Tractor Co.
Deere and Co.
E. I. du Pont de Nemours & Co.
Fafnir Bearing Co.
Ford Motor Co.
Gulf Research & Development Co.
Holcroft Corp.
E. F. Houghton & Co.
Hughes Tool Co.
Reed Roller Bit Co.
W. S. Rockwell Co.
Sinclair Research Laboratory, Inc.
Surface Combustion Corp.
SKF Industries, Inc.
Timken Roller Bearing Co.
White Motor Co.
Engineering Foundation
Columbia University

Standard Commercial Wrought Copper and Brasses, Nonleaded and Leaded

Compiled by Arthur H. Allen from data published by the Copper & Brass Research Assoc. (Revised to August 15, 1952)

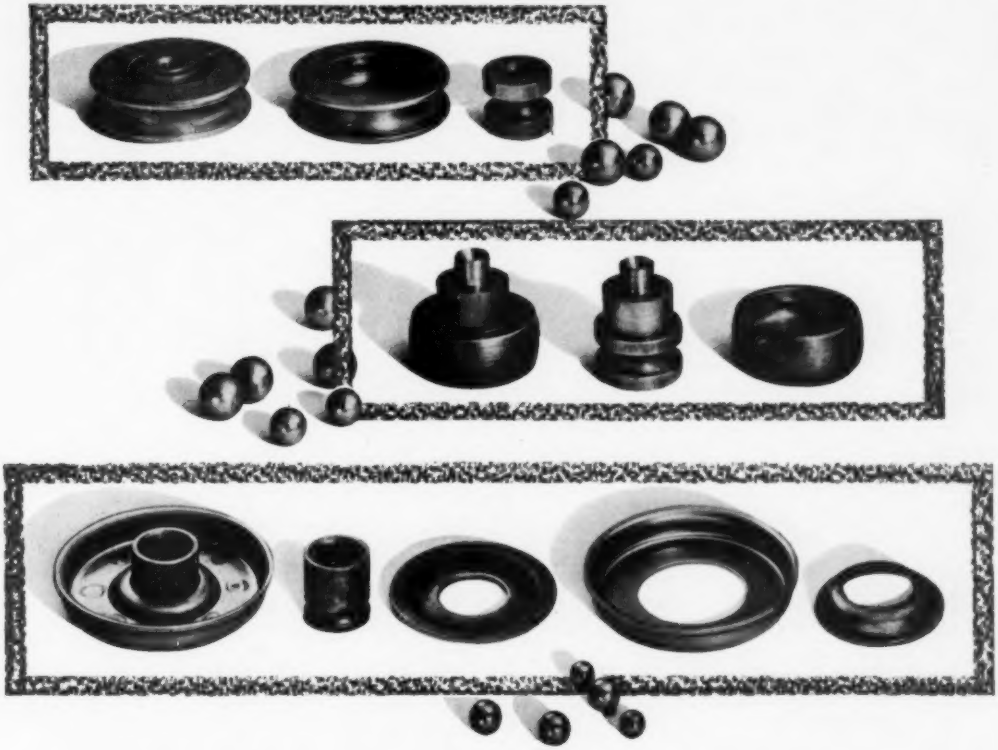
Names (Current and Obsolete)	Nominal Composition, %	Forms Most Commonly Ordered, Indicated by (*) or by Reference to Nearest Applicable A.S.T.M. Specification					Mechanical Properties, Hard and Soft (Range), All Forms				Fabrication Processes	Fabricating Properties
		Rolled Flats	Drawn Rods and Flats	Shapes	Wire (Except Flat)	Tube	Tensile†	0.5% Yield†	Elongation in 2 In.	Shear†		
Coppers												
Electrolytic tough pitch	Cu + O, 100	B48 B124, No. 12 B133 B152 B187	B48 B124, No. 12 B133 B187	B124, No. 12 B133 B187	B1, B2 B3, B33 B47, B49 B189	B188	66—32	50—10	55—4	33—22	Blanking, coining, coppersmithing, drawing, etching, forming, bending, heading, upsetting, hot forging, pressing, piercing, punching, roll threading and knurling, shearing, spinning, squeezing, swaging, stamping	Excellent hot or cold working; machinability rating 20; excellent soft soldering; good silver brazing; poor oxy-acetylene or resistance welding, fair carbon arc welding
Deoxidized Obs: Phosphorized copper	Cu + P, 100	B124, No. 12 B133 B152	B124, No. 12 B133	B124, No. 12 B133	—	B42, B68 B75, B88 B111	55—32	50—10	45—8	29—22	Same as for electrolytic copper	Excellent hot or cold working; machinability rating 20; excellent soft soldering and silver brazing; good carbon arc welding, fair oxy-acetylene welding, poor resistance welding
Brasses—Nonleaded												
Gilding, 95% Obs: Commercial bronze, 95% Gilding metal	Cu 95 Zn 5	B36, No. 1 B134, No. 1	B134, No. 1	—	B134, No. 1	—	64—34	58—10	45—4	40—28	Blanking, coining, drawing, etching, forming and bending, piercing and punching, shearing, spinning, squeezing and swaging, stamping	Excellent cold, good hot working; machinability rating 20; excellent soldering and brazing; good carbon arc, fair oxy-acetylene and poor resistance welding
Commercial bronze, 90% Obs: Gilding metal Commercial bronze	Cu 90 Zn 10	B36, No. 2 B130 B134, No. 2	B134, No. 2	—	B134, No. 2	*	90—37	62—10	50—3	42—28	Blanking, coining, drawing, etching, forming and bending, heading and upsetting, hot forging and pressing, piercing and punching, roll threading and knurling, shearing, spinning, squeezing and swaging, stamping	Same as for above (gilding, 95%) except a trifle bett.r oxy-acetylene welding
Red brass, 85% Obs: Rich low brass	Cu 85 Zn 15	B36, No. 3 B134, No. 3	B134, No. 3	—	B134, No. 3	B43 B111 B135, No. 1	105—39	63—10	48—3	54—31	Blanking, coining, drawing, etching, forming and bending, heading and upsetting, piercing and punching, roll threading and knurling, shearing, spinning, squeezing and swaging, stamping	Excellent cold, good hot working; machinability rating 30; excellent soldering and brazing; good oxy-acetylene and carbon arc welding, poor resistance welding
Low brass, 80% Obs: 80-20 brass Low brass	Cu 80 Zn 20	B36, No. 4 B134, No. 4	B134, No. 4	—	B134, No. 4	—	125—42	65—12	55—3	60—32	Same as for red brass	Same as for red brass except not quite so good in hot-work qualities and a little inferior for brazing and carbon arc welding
Cartridge brass, 70% Obs: Spinning brass Spring brass Extra quality brass 70-30 brass	Cu 70 Zn 30	B19 B36, No. 6 B134, No. 6	B134, No. 6	—	B134, No. 6	B14 B135, No. 2	130—44	65—11	66—3	60—32	Blanking, drawing, etching, forming and bending, heading and upsetting, piercing and punching, shearing, spinning, squeezing and swaging, stamping	Excellent cold, fair hot working; machinability rating 30; excellent soldering, good brazing; good oxy-acetylene, fair carbon arc and resistance welding
Yellow brass Obs: Drawing brass Common high brass Hoop brass	Cu 65 Zn 35	B36, No. 8 B134, No. 7	B134, No. 7	—	B134, No. 7	—	128—46	62—14	65—3	60—32	Same as for cartridge brass with addition of roll threading and knurling	Excellent cold, poor hot working; machinability rating 30; excellent soldering; good brazing; good oxy-acetylene, fair carbon arc and resistance welding
Muntz metal Obs: Yellow metal	Cu 60 Zn 40	*	*	—	*	B111 B135, No. 5	74—54	55—20	52—10	45—39	Blanking, forming and bending, hot forging and pressing, hot heading and upsetting, shearing	Fair cold, excellent hot working; machinability 40; excellent soldering, good brazing; good to fair welding
Leaded Brasses												
Leaded commercial bronze Obs: Hardware bronze	Cu 89 Pb 1.75 Zn 9.25	—	B140, Alloy B	B140, Alloy B	—	—	60—52	50—12	45—10	32—24	Machining	Good cold, poor hot working; machinability 80; excellent soldering and brazing; fair to poor welding
Low-leaded brass (tube) Obs: Tube brass High brass	Cu 66 Pb 0.5 Zn 33.5	—	—	—	—	B135, No. 3	75—47	60—15	60—7	—	Forming and bending, machining, piercing and punching	Excellent cold, poor hot working; machinability 60; excellent soldering; good brazing; fair welding
Low-leaded brass Obs: Butt brass	Cu 65 Pb 0.5 Zn 34.5	B121, No. 2	—	—	—	—	74—46	60—14	65—8	43—32	Blanking, drawing, machining, piercing and punching, stamping	Good cold, poor hot working; machinability 60; excellent soldering; good brazing; fair welding
Medium-leaded brass Obs: Engraver's brass Matrix brass Tack brass Common leaded clock brass	Cu 65 Pb 1 Zn 34	B121, No. 3	*	*	*	—	88—47	60—15	60—7	46—34	Blanking, heading and upsetting, machining, piercing and punching, roll threading and knurling, stamping	Good cold, poor hot working; machinability 70; excellent soldering; good brazing; fair welding, except resistance
High-leaded brass (tube) Obs: Free-cutting tube brass	Cu 66 Pb 1.6 Zn 32.4	—	—	—	—	B135, No. 4	75—52	60—20	50—7	—	Machining, piercing and punching	Fair cold, poor hot working; machinability 80; soldering excellent; silver brazing good; welding fair, except resistance
High-leaded brass Obs: Clock brass Engraver's brass	Cu 65 Pb 2 Zn 33	B121, No. 4 B121, No. 5	*	—	—	—	85—40	62—17	52—7	45—34	Blanking, machining, piercing and punching, roll threading and knurling, stamping	Fair cold, poor hot working; machinability 90; soldering excellent; brazing good; welding fair, except resistance
Extra-high-leaded brass Obs: Block brass Rule brass	Cu 63 Pb 2.5 Zn 34.5	B121, No. 6	—	—	—	—	75—49	60—17	50—7	—	Blanking, machining, piercing and punching, stamping	Poor cold, fair hot working; machinability 100, equal to free-cutting brass; easily soldered or brazed; welding fair to poor
Free-cutting brass Obs: Free-turning brass	Cu 61.5 Pb 0.6 Zn 39.4	—	B16	*	—	—	68—40	52—18	53—18	38—30	Machining, roll threading and knurling	Poor cold, fair hot working; machinability 100; easily soldered or silver brazed; welding qualities fair to poor
Leaded muntz metal Obs: muntz metal	Cu 60 Pb 0.6 Zn 39.4	B171	—	—	—	—	54 (as rolled)	20	45	40	Machining	Fair cold, excellent hot working; machinability 60; easily soldered or brazed, welding fair to poor
Free-cutting muntz metal Obs: Half-leaded muntz Leaded muntz	Cu 60 Pb 1 Zn 39	—	—	—	—	B135, No. 6	80—54	60—20	40—6	—	Machining	Same as leaded muntz metal except machinability is up to a rating of 70
Forging brass	Cu 60 Pb 2 Zn 38	B124, No. 2	B124, No. 2	B124, No. 2	—	—	52 (as extruded)	20	45	—	Heading and upsetting, hot forging and pressing, hot heading and upsetting, machining	Poor cold, excellent hot working; machinability 80; easily soldered or brazed; welding fair to poor
Architectural bronze	Cu 57 Pb 3 Zn 40	—	*	*	—	—	60 (as extruded)	20	30	35	Hot forging and pressing, hot forming and bending, machining	Poor cold, excellent hot working; machinability 90; excellent soldering; good brazing; fair to poor welding

Notes

Alloys herein listed are standard in the sense that over a period of years they have been the ones most commonly used in larger quantities. In addition to them, there are many special and proprietary alloys which are produced by mills for various uses, including such materials as aluminum bronzes, cadmium bronzes, beryllium coppers, aluminum-tin bronzes, aluminum-silicon bronzes, silicon bronzes, copper-chromium alloys and other combinations for special applications.

* Forms commonly ordered.

† Tensile strength, yield strength at 0.5% strain, and shear strength are given in units of 1000 psi., and the range is from hardest to softest commercial forms attained by cold work, heat treatment, or both.



By John Chipman, Professor in Charge, Department of Metallurgy
Massachusetts Institute of Technology, Cambridge, and Past President, ⊕

Chemical Behavior of Sulphur in Iron and Steelmaking

OF THE SEVERAL harmful impurities which the metallurgist has had to combat in producing steels of high quality, the one which has presented the greatest problems, at least in American practice, is sulphur. Its deleterious effects in quantities greater than a few hundredths of one per cent are too well known to require elaboration. Methods for controlling sulphur in steel have consisted either of adding some element which forms a stable sulphide or, more commonly, using a strongly basic slag as a refining agent. This much of the chemistry of sulphur has been known for many years. Until recently, however, quantitative relationships were scarcely known and the limitations placed upon its removal by the laws of thermodynamics had not been investigated. It is the purpose of the following discussion to show how our knowledge of the chemical behavior of sulphur at high temperatures has been expanded in recent years through laboratory research.

Desulphurizing Power of Openhearth Slags — In order to study the desulphurizing power of a slag, a very simple criterion can be found in the limiting distribution ratio for sulphur between slag and metal under equilibrium conditions. If, in a small furnace, molten metal and slag are allowed to remain in contact for a sufficiently long period so the slag has removed from the metal all of the sulphur that it can take, then the ratio ($\%$ S)/[$\%$ S] determined by analysis of the slag and metal constitutes a desulphurizing index for the slag. For slags whose compositions correspond to those used in basic openhearth furnaces, the desulphurizing indices were studied in my laboratory by Karl Fetters[1] some 13 years ago. His studies were resumed and extended to a wider range of slag compositions by N. J. Grant[2] in 1946. The type of furnace they used is illustrated in Fig. 1. This is a high-frequency induction furnace having a crucible about 20 cm. (7¾ in.) in diameter and holding a charge of about 30 kg. (65 lb.). The stirring effect which accompanies inductive heating assures adequate slag-metal contact and hastens attainment of equilibrium. Since the slag is not heated by induction, it would be colder than the bath except for the arc between the carbon electrodes whereby it was possible to maintain the slag at approximately metal temperature. To protect the electrodes and the metal from oxidation a nitrogen atmosphere was employed; this was found to have the added advantage that the transfer of carbon from electrodes to metal was practically nil.

This series of experiments showed that the desulphurizing power of the slag increased with increasing basicity. As a measure of the slag basicity we used a quantity called excess base[3] obtained by adding the molar concentration of the basic oxides CaO, MgO and MnO in the slag and subtracting from this the sum of the equivalent concentrations of the acid oxides SiO_2, P_2O_5, Fe_2O_3 and Al_2O_3. It is noted that FeO is not included; the indications of our experiments are that it has little effect on desulphurizing power of the slag within the range of compositions encountered in the openhearth.

The results of this study are very well summarized in Fig. 2, in which the desulphurizing index is plotted against excess base. The three basic oxides mentioned above were found to be equally effective; slags high in MnO were as good desulphurizers as those high in CaO. Slags containing different amounts of FeO are reported in the plot by

[1] "Equilibria of Liquid Iron and Slags of the System CaO-MgO-FeO-SiO_2", by K. L. Fetters and John Chipman, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 145, 1941, p. 95.

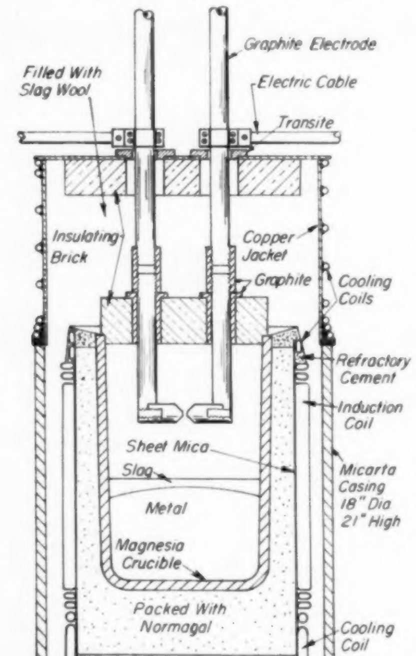
[2] "Sulphur Equilibria Between Liquid Iron and Slags", by N. J. Grant and John Chipman, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 167, 1946, p. 134.

[3] Excess base $= nCaO + nMgO + nMnO - 2nSiO_2 - 4nP_2O_5 - 2nAl_2O_3 - nFe_2O_3$, where n is the number of moles in 100 g. of slag.

Studies of Openhearth Slags

different symbols; since the plotted points straddle the average or standard line, the result is essentially independent of the FeO content of the slag. The same group of data is shown in Fig. 3, wherein different symbols represent results at different narrow temperature ranges. Again it is seen that, within the range of temperatures encountered in the openhearth, temperature has no sensible effect on the limiting desulphurizing power of the slag. In practice, of course, higher temperature may result in more rapid desulphurization, but in our experiments the limiting ratio, *when enough time is provided*, is independent of temperature. The

Fig. 1 — Induction Furnace With Carbon Arc for Heating the Slag Used by Fetters and Grant in the Author's Laboratory for Studying the Distribution of Sulphur Between Metal and Slag



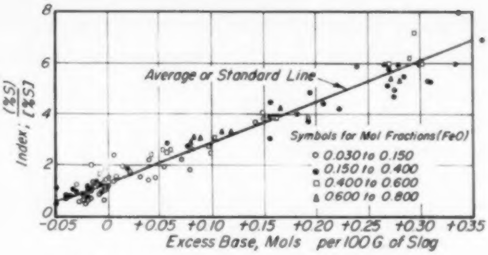


Fig. 2 — Variations in Iron Oxide in Basic Openhearth Slag Have No Discernible Influence on Desulphurizing Power, Since Their Plots Straddle the Standard Line

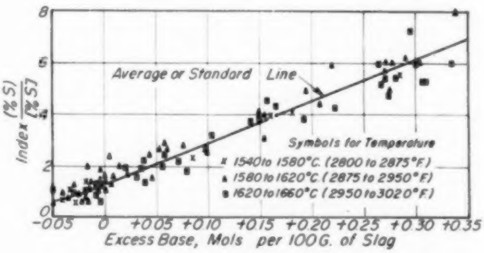


Fig. 3 — Desulphurizing Index (at Equilibrium) of Basic Openhearth Slags Is Not Affected by Temperature Within the Range of 1540 to 1660° C.

desulphurizing index of these slags lies in the range from about 1 to 8. This will be compared presently with the results of similar experiments on blast furnace-type slags.

Blast Furnace Slags — A similar study of slags such as occur in blast furnace practice was carried out in my laboratory by G. G. Hatch.[4] For this study a high-carbon metal was desired and the crucible was therefore made of graphite, and a uniform temperature for both slag and metal was obtained by induction heating. One disadvantage of graphite as a container is that it shields the metal from the stirring effect of high frequency. For this reason an unduly long time would be required to reach equilibrium with mechanical stirring, so the furnace shown in Fig. 4 employed a simple graphite stirring mechanism and operated in an atmosphere of carbon monoxide. Equilibrium was reached rather slowly in spite of the stirring; in many instances the sulphur content was still decreasing after 4 hr. and did not reach its final steady level until 6 or 8 hr. had elapsed. This slow approach to the final equilibrium seemed very mysterious to us at the time, since

[4] "Sulphur Equilibria Between Iron Blast Furnace Slags and Metal", by G. G. Hatch and J. Chipman, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 167, 1946, p. 134.

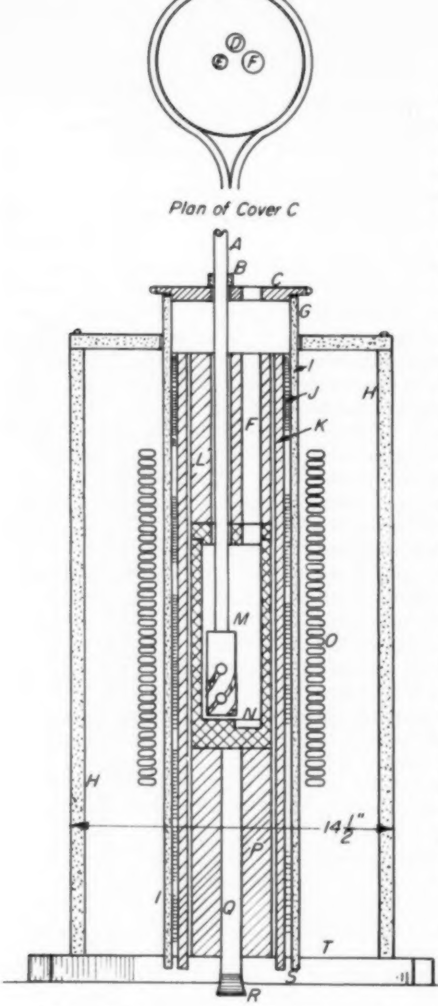


Fig. 4 — Furnace Used for Blast Furnace Slags

- A Stirring rod
- B Brass bushing
- C Water-cooled brass cover
- D Gas inlet
- E Hole for stirrer
- F Pyrometer hole
- G Rubber gasket
- H Transite frame
- I Silica tube
- J Lampblack packing
- K Porous carbon tube
- L Porous carbon block
- M Graphite crucible
- N Sampling well
- O Induction coil
- P Porous carbon block
- Q ¾-in. hole
- R Rubber stopper
- S Silicone gasket
- T Soapstone base

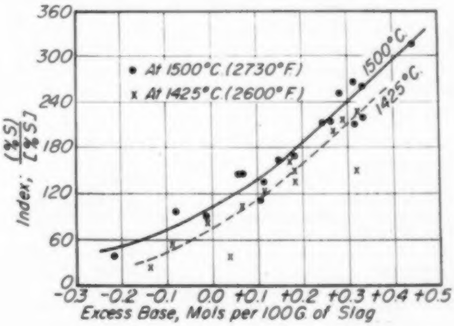
about 95% of the sulphur could be removed from the metal very quickly. The reason for this slow transfer as equilibrium was approached was not understood until quite recently; it will be discussed in a later section. Results obtained, when enough hours were allowed to secure complete equilibrium between slag and metal at 1500° C. (2730° F.), are summarized in the circles and heavy line in Fig. 5. These slags are less basic (by any of the usual criteria) than those of Fig. 2 and 3, and, accordingly, we have used a different measure of excess base.[5] But despite the much lower basicity, the desulphurizing index varies over a range from about 50 to 350.

Why is it that blast furnace-type slags have desulphurizing indices 50 times as great as openhearth-type slags? Possible answers are to be sought in the three principal points of difference between the two sets of experiments. Briefly, these are *(a)* the temperature, *(b)* the composition of the metal and *(c)* the composition of the slag.

The blast furnace slag data refer to a temperature of 1500° C. (2730° F.). A similar set of experiments was run at 1425° C. (2600° F.) and the results establish a trend from which we may estimate the indices at 1600° C. (2910° F.), the temperature of the openhearth slag experiments. Figure 5, where these experiments are shown by crosses, indicates that the desulphurizing index increases with increasing temperature. We can estimate from this figure that at 1600° C. a still higher index

[5]Here excess base = $nCaO + \frac{2}{3}nMgO - nSiO_2 - nAl_2O_3$, where n is the number of mols per 100 g. of slag and ⅔ is an empirical factor.

Fig. 5 — Distribution of Sulphur Between Blast Furnace-Type Slag and Metal at 1500° C. (2730° F.) and at 1425° C. (2600° F.)



would be obtained and, furthermore, that at this temperature the blast furnace index is higher than the openhearth desulphurizing index by a factor of 60 to 80. The two processes are thus seen to be quite different with respect to temperature. The blast furnace-type reaction is definitely affected by temperature, the openhearth-type is not.

ACTIVITY OF SULPHUR IN THE METAL BATH

An experimental system involving the metal phase and entirely independent of the slag has been used in a study of the reaction of sulphur in the liquid metal with hydrogen to form hydrogen sulphide. The experimental arrangement is shown in Fig. 6. The liquid metal containing sulphur is held in a small alumina crucible and heated by high-frequency induction, rapidly stirring it and thus bringing it into very good contact with the gas stream. The atmosphere is a controlled mixture of hydrogen sulphide and hydrogen. Samples are taken from the metal bath by inserting a silica tube in the upper part of the furnace and withdrawing one or two grams of metal which solidifies in the silica tube. Since the bath contains about 175 g., a considerable number of samples can be obtained during a run. The run is continued until the sulphur analysis becomes constant. The relationship between gas composition and sulphur content of pure iron-sulphur alloys has been determined by Sherman and Elvander.[6] Their results for melts containing 1% sulphur or more show a deviation from Henry's law, but in the range of composition up to about 0.5% sulphur this deviation is slight enough to be ignored. The full line in Fig. 7 has therefore been drawn from their work.

When alloying elements are added to the bath the result may be quite different. Figure 7 shows a few typical results obtained by Sherman[7] and it is noted that the effect of carbon and silicon is to increase the $H_2S : H_2$ ratio for a given percentage of sulphur. The significance of this result is that carbon and silicon increase the "escaping tendency" or the activity of sulphur. This is most easily recorded as an activity coefficient which is computed as follows:

[6] "Thermodynamic Properties of Sulphur in Molten Iron-Sulphur Alloys", by C. W. Sherman, H. I. Elvander, and J. Chipman, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 188, 1950, p. 334.

[7] "Influence of Phosphorus on the Activity of Sulphur in Liquid Iron", by C. W. Sherman and J. Chipman, *Revue de Métallurgie*, Vol. 48, 1951, p. 613; *Transactions*, Amer. Inst. of Mining and Metallurgical Engineers, 1952, p. 597.

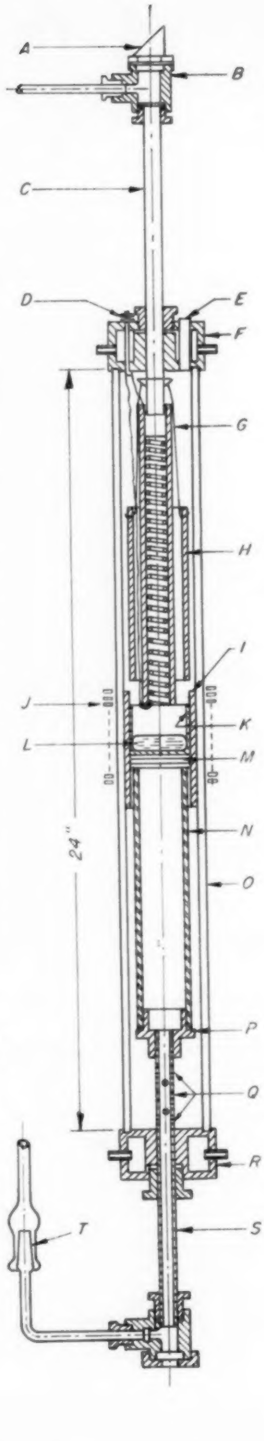


Fig. 6 — Apparatus for Studying Reaction Between Hydrogen and Sulphur

- A Glass prism
- B Glass window
- C Pyrex tubing
- D Terminals for the preheater
- E Sampling hole
- F Water-cooled brass head
- G Preheater
- H Radiation shield of Alundum
- I Heat insulation of Alundum
- J Induction coil
- K Crucible
- L Melt
- M Alundum disks
- N Supporting tube of Alundum
- O Quartz tube
- P Stainless steel supporting disk
- Q Holes for gas outlet
- R Brass head
- S Stainless steel tube
- T Ground glass joint

Computing Activity Coefficient

The observation at 2% carbon and 2% silicon, for example, shows a ratio of $H_2S:H_2$ which is greater than would be encountered in a simple iron-sulphur alloy of the same sulphur content by a factor of 2.5. In this alloy, then, the activity coefficient of sulphur is 2.5. On the other hand, in the presence of 6.3% manganese, the activity coefficient is reduced to 0.69.

In a similar manner a large number of ternary, quaternary and more complex alloys were investigated. The results are in very good agreement with recent researches of Morris, Williams and Buehl, and of Rosenqvist and Cox;[8] the data are summarized in Fig. 8. In this diagram it should be noted that the logarithm of the activity coefficient of sulphur, log f_s, is plotted against percentage concentration of the third component. It was found experimentally that the relationship for each added element is independent of sulphur content and is linear at low concentrations of this added component. Curvature sometimes appears in the graphs at higher concentration.

A method has been devised for predicting from Fig. 8 the activity coefficient of sulphur in more complex alloys and pig irons of various compositions. Within the range of compositions in which a straight line is plotted in Fig. 8, the values of log f_s can be combined by simple algebraic addition. When the line becomes curved, however, an empirical means of taking proper account of the curvature is required. Beginning with the straightest lines of Fig. 8 and proceeding to those of successively greater curvature, the method is as follows:

Consider a hypothetical blast furnace cast with composition as follows:

P	2.00%	S	0.15%
Si	1.20	Cu	0.05
C	3.75	Mn	2.00

The elements which give positive contributions to the activity coefficient are arranged on the left; negative contributions are shown on the right.

The value for P = 2.00% is located at A in Fig. 8 below, and log f_s is equal to 0.08. A point on the silicon curve B is located of equal f_s and this corresponds to 1.30% Si;

[8] "The Effect of Silicon on the Activity of Sulphur in Liquid Iron", by J. P. Morris and A. J. Williams, Jr., *Transactions*, American Society for Metals, Vol. 41, 1949, p. 1425.

"The Effect of Carbon on the Activity of Sulphur in Liquid Iron", by J. P. Morris and R. C. Buehl, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 188, 1950, p. 317.

"The Activity of Sulphur in Liquid Steel; the Influence of Copper", by T. Rosenqvist and E. M. Cox, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 188, November 1950, *Journal of Metals*, p. 1389-1393.

Fig. 7 — Relationship Between Gas Composition (Mixture of Hydrogen and Hydrogen Sulphide) and Sulphur in Pure Iron Plotted as a Straight Line. Activity coefficient of sulphur at any point on line is unity. Manganese in the metal reduces the activity coefficient of sulphur, whereas carbon, silicon, aluminum and phosphorus increase it

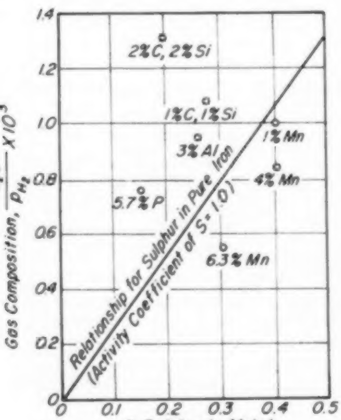
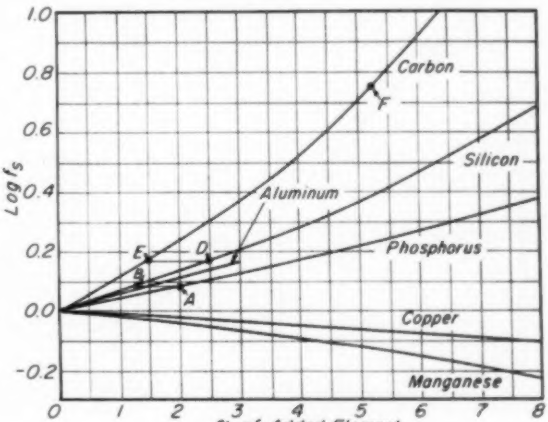


Fig. 8 — Activity Coefficient of Sulphur (Expressed Here as Log f_s) Varies With Kind and Amount of Alloying Element in the Iron



Desulphurizing Pig Iron

that is, 1.30% Si has the same influence as does 2.00% P. Add to 1.30 the 1.20% Si in the alloy and locate D for 2.50% Si and project horizontally to E on the carbon line. This equals 1.50% (the carbon equivalent of both phosphorus and silicon in the alloy). Since there is also 3.75% C in the iron, the total of positive contributions is equivalent to that of 5.25% C (point F in Fig. 8) and log $f_s = +0.75$ for this amount.

Both sulphur and copper are so low as to have negligible effects, and the only negative contribution is -0.05 for 2% manganese.

For the iron assumed, log f_s is the algebraic sum, that is $+0.75 - 0.05$ or 0.70, and f_s, the activity coefficient of sulphur in this iron, is 5.0.

Calculations for pig irons of various compositions show that on the average the activity coefficient of sulphur in pig iron is about 5 to 6, which means that it has five to six times the tendency to get out of pig iron that it would have in a simple iron-sulphur alloy or a low-carbon steel bath of equal sulphur content.

Desulphurization — A direct application of this result is found in a study of the desulphurizing effect of manganese.

It is a very well-known fact that a pig iron of high manganese content, if held in the ladle or mixer, may lose part of its sulphur during cooling by the precipitation of an impure manganese sulphide. The solubility of this manganese sulphide in pig irons has been studied most recently by Oelsen[9] and his results are shown in Fig. 9. The corresponding study in carbon-free iron was carried out by C. Sherman in my laboratory and his results are shown for comparison in the uppermost line of Fig. 9. If we interpolate between Oelsen's results to a temperature corresponding to Sherman's experiments, we find that for a given manganese content of the metal the sulphur concentration is approximately one fifth as great in pig iron as in the simple Fe-S alloy.

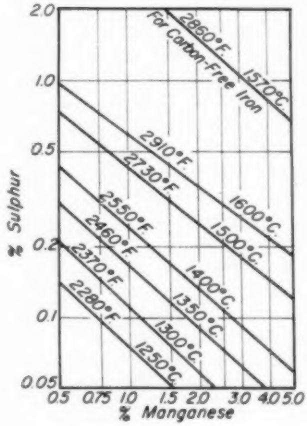
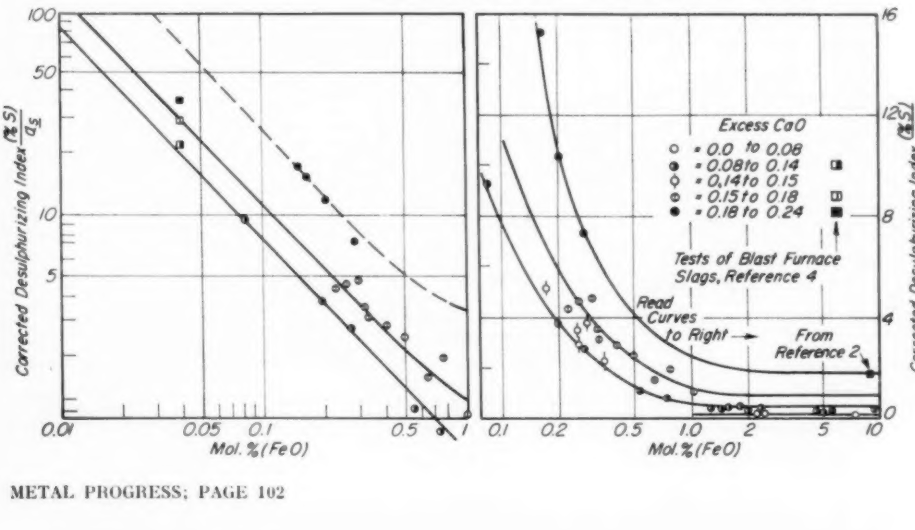


Fig. 9 — Effect of Manganese on the Solubility of Manganese Sulphide in Molten Pig Iron at Various Temperatures, Indicating the Tendency for Sulphur to Be Eliminated in the Mixer. (Pig iron data by Oelsen)

[9] "Scientific Principles of Metallurgical Processes", by Willy Oelsen. Fiat Review of German Science, 1939-1946, Vol. 27, Inorganic Chemistry, Part V.

Fig. 10 — At Right: Effect of Iron Oxide in the Slag Upon Its Desulphurizing Index. Slags are of intermediate basicity. Temperature 1550 to 1700° C. (2820 to 3090° F.). At left: Logarithmic extrapolation of the data to the range of blast furnace slags, very low in (FeO)



On the basis of metal composition alone it should be five to six times as easy to desulphurize pig iron as low-carbon steel, other things being equal. The fact is, however, that other things are *not* equal and, instead of being six times as easy, it may be much easier or much more difficult, depending on conditions in the particular furnace or plant. The coefficient of 5 to 6 represents on the average those factors in the desulphurization of pig iron which have to do with the effects of metal composition. We find empirically, however, that the desulphurizing index for slags of the pig iron type may be from 60 to 80 times greater than for openhearth slags. The effect of the slag itself must therefore be to raise the desulphurizing index by a factor of 10 to 15.

COMPOSITION OF SLAG AND DESULPHURIZING POWER

Let us now examine the effects of differences in slag composition. We have used a quantity called "excess base" to represent the slag's composition, and it should be remembered that this has been defined differently for openhearth and for blast furnace-type slags. In the former, it was the excess of $CaO+MgO+MnO$ above that required to form compounds of the type $2CaO \cdot SiO_2$. Most of the blast furnace slags are acid by this criterion, and for these we have used the excess base above that required to form compounds of the type $CaO \cdot SiO_2$.

Thus, the composition ranges shown in Fig. 2 and 5 (which appear to be similar) are actually rather different, the openhearth slags extending to higher basicity. If compared at identical values of excess base or of lime-silica ratio, the desulphurizing index of the blast furnace experiments is actually more than 100 times the desulphurizing index found under openhearth-type slags.

It was pointed out when discussing the openhearth slags that the effect of FeO on the desulphurizing index is quite negligible — provided the results are expressed as in Fig. 2 and that the FeO content of the slag lies in the range of 3 to 80%. In the blast furnace type of slags the principal point of difference lies in the very low FeO content. It becomes then a matter of some importance to investigate the effect of FeO on the desulphurizing power of the slag in a range of compositions extending from 3% FeO down to the small concentrations that are found in blast furnace slags. Moreover, this is the composition range which is of primary interest in basic electric furnace practice.

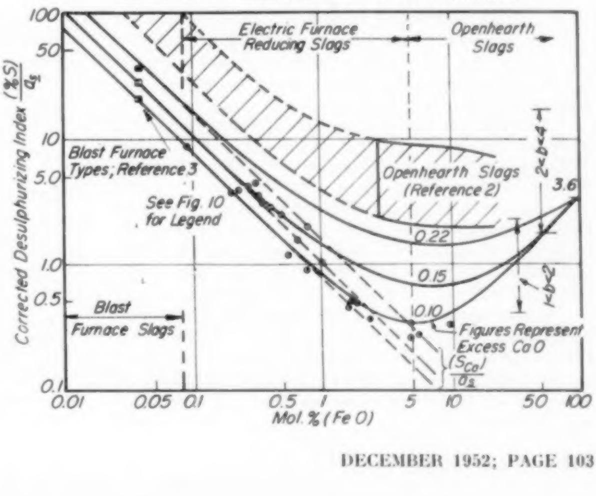
This study was recently carried out in my laboratory by Roberto Rocca.[10] He used the same furnace that had been used in Grant's studies (Fig. 1) and in order to secure low concentrations of FeO, he worked with a bath containing appreciable quantities of silicon. It happened that during this period the results of Morris and Williams[8] on the effect of silicon on the activity coefficient of sulphur became available. We were thus enabled to correct for this effect of silicon by using a corrected desulphurizing index represented by

$$\frac{(\%\ S)}{f_s \times [\%\ S]}$$

A typical group of Rocca's results is shown in Fig. 10 at right. The corrected desulphurizing index is shown as ordinate and the molecular % FeO as abscissa. The important finding here is that when the concen-

[10] "Distribution of Sulphur Between Liquid Iron and Slags of Low Iron-Oxide Concentrations", by R. Rocca, N. J. Grant, and J. Chipman, *Journal of Metals*, April 1951, *Transactions*, American Institute of Mining and Metallurgical Engineers, p. 319.

Fig. 11 — Desulphurizing Power of Slags as It Varies With Amount of Iron Oxide Contained



Chemistry of Desulphurization

tration of FeO drops below 1%, a further decrease will result in a great improvement in the desulphurizing index. This improvement extends throughout the range of concentrations found in basic electric slags.

The data in the region below 1% FeO fit a straight line on a logarithmic plot as shown at the left of Fig. 10, and the indication is that at higher concentrations of FeO the desulphurizing index should become extremely small — as indeed is shown by Rocca's data. It is known, however, from the work of Bardenheuer and Geller[11] that if the slag consists essentially of FeO, the desulphurizing index is about 3.6. It follows that somewhere between 1% and 100% FeO there may be a minimum in the desulphurizing index, and evidence for this minimum is found in some of the less basic slags in the region of about 5% FeO.

Figure 11 summarizes this situation. The lower three curves in full lines refer to slags of intermediate basicity; they are in part schematic, and extend from pure iron oxide on the right hand down to low concentrations of FeO found in blast furnace slags at the left. It is of interest to mention that the very low concentrations corresponding to the uppermost points at the left end of these curves, taken from Hatch's work,[2] represent an average of FeO analyses made after very complete magnetic separation of the crushed slag. Without this precaution blast furnace slags contain particles of metal which appear on analysis as FeO.

A complete view of the effects of basicity and FeO is shown in Fig. 11, even though the data on slags of high basicity ($2<b<4$) are somewhat less complete and are represented by the shaded area which has been studied experimentally only in the high FeO range. This diagram explains the apparently anomalous findings of a very marked effect of FeO at low concentrations, whereas results of Grant and Chipman[2] indicate no effect in the high FeO range.

A chemical explanation of these findings is not too difficult to deduce. In the oxidizing slags there is a distribution of sulphur between slag and metal conditioned principally by the reaction:

$$\text{CaO (slag)} + \underline{S} = \text{CaS (slag)} + \underline{O} \qquad (1)$$

where the underlined symbols represent elements dissolved in the steel bath. From the viewpoint of ionic theory this may be written:

$$O^{--} + \underline{S} = S^{--} + \underline{O} \qquad (1a)$$

In the region of low FeO content, the concentration of oxide ion, O^{--}, is fixed by the excess base. Hence, for constant basicity it follows from (1a) that:

$$\frac{(S^{--})}{[S]} = \frac{K}{[O]} \qquad (2)$$

and if the oxygen in the bath is proportional to FeO in the slag this reduces to

$$\text{Log}\,\frac{(S)}{[S]} = \log K - \log\ (\%\ \text{FeO}) \qquad (3)$$

an equation which is verified by the straight lines of Fig. 10 (left) and which is not valid above about 1% FeO. At higher concentrations other treatments may be used, such as the simple plotting methods of Fig. 9 to 11, the more analytical treatment of Darken and Larsen,[12] or the detailed ionic formulation of Flood and Grjotheim.[13]

At the very low concentrations of FeO corresponding to blast furnace conditions the oxygen content of the metal is limited by the presence of carbon with which the bath is saturated. Under such circumstances the reaction is more simply expressed by the equation:

$$\text{CaO} + \underline{S} + \underline{C} = \text{CaS} + \text{CO} \qquad (4)$$

or, in the presence of a sufficient concentration of silicon:

$$2\text{CaO} + 2\underline{S} + \text{Si} = 2\text{CaS} + \text{SiO}_2 \qquad (5)$$

These equations represent reactions whose powerful desulphurizing effect is dependent upon the low oxygen pressure that is associated with metal which is high in either carbon or silicon.

Reaction (5) has been studied in blast furnace slags by Oelsen and Maetz,[14] who have shown that the mass-action index,

$$\frac{(S)}{[S]\sqrt{[Si]}}$$

[11] "Ueber die Grundlagen der Entschwefelung Von Roheisen und Stahl", by P. Bardenheuer and W. Geller, *Mitteilungen*, Kaiser Wilhelm Institut für Eisenforschung, Vol. 16, 1934, p. 77-91.

[12] "Distribution of Manganese and of Sulphur Between Slag and Metal in the Openhearth Furnace", by L. S. Darken and B. M. Larsen, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 150, 1942, p. 87.

[13] "Thermodynamic Calculation of Slag Equilibria", by H. Flood and K. Grjotheim, *Journal*, Iron and Steel Institute, Vol. 171, 1952, p. 64 to 70.

[14] "Beitrage zur Metallurgie des Hochofenn", by Willy Oelsen and Helmuth Maetz, *Stahl und Eisen*, Vol. 69, 1949, p. 147.

Accelerating Transfer Rate

is a function of lime-silica ratio.

A modification of reaction (4), in which CaO, CaS and coke are all present as solids, has been used by Kalling, Danielsson and Dragge[15] as the basis for a practical method for desulphurization of hot metal. They have obtained results well below 0.01% S at temperatures around 1250 to 1300° C. (2280 to 2375° F.) and this is confirmed in plant practice by Fornander.[16]

This is fully in accord with the laboratory results of Rosenqvist[17] in which he determined the relative stability of calcium sulphide and oxide through the equilibrium:

$$CaS\ (s) + H_2O\ (g) = CaO\ (s) + H_2S\ (g) \qquad (6)$$

From his results, with the aid of additional thermodynamic data which may be found in the A.I.M.E.'s book (1951) "Basic Open Hearth Steelmaking", Chapters 14 and 16, it is possible to calculate the equilibrium constant for the reaction:

$$CaO\ (s) + \underline{S} + C\ (s) = CaS\ (s) + CO\ (g);$$

$$K = \frac{p_{CO}}{a_S} \qquad (7)$$

The calculation indicates that at 1300° C. (2375° F.) the value of K is 155, or that at atmospheric pressure of CO, the activity of sulphur is 0.0065. Since the activity coefficient is about 5 or 6, this corresponds to about 0.001% sulphur under equilibrium conditions. Of course, equilibrium is not actually reached and the success of the process depends upon the rate at which equilibrium is approached.

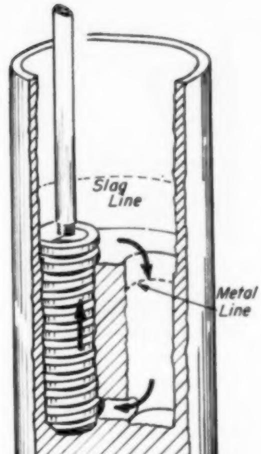


Fig. 12 — Graphite Crucible and Stirrer as Redesigned to Secure Rapid Stirring of Slag and Metal. Lower part of graphite crucible consists of a graphite block with two $1\frac{1}{8}$-in. holes, one carrying a helical graphite screw with four square threads per in.

RATE OF REMOVAL OF SULPHUR

In controlling sulphur in blast furnace iron, equilibrium between slag and metal is not generally attained. The desulphurizing index, as we have defined it, is therefore not the only criterion of efficient desulphurization. The rate of transfer of sulphur from metal to slag becomes a matter of equal importance. It will be recalled that in the experiments of Hatch[4] the final approach to equilibrium was unexpectedly slow. Further investigation of this point was undertaken by N. J. Grant and Ulf Kalling,[18] and at the same time an attempt was made to discover how the desulphurizing power of the slag was affected by the presence of manganese.

It was reasoned that the transfer of sulphur could be accelerated by more rapid stirring of the slag-metal system. To this end the graphite crucible and stirrer were redesigned as shown in Fig. 12. With rapid spinning of the helical member small droplets of metal were thrown upward into the slag layer and excellent mixing of the two phases was obtained. In the new apparatus the rate of removal of sulphur from metal containing initially 1.65% S by slags of four typical compositions is shown at the left of Fig. 13 (page 106). The initial rate of transfer was fast enough but the approach to equilibrium no faster than had been obtained by Hatch with his simple stirring arrangement. A reasonably rapid sulphur transfer was obtained with the more strongly basic slags, but the higher the silica content the slower was the rate of transfer.

Effect of MnO — A series of similar ex-

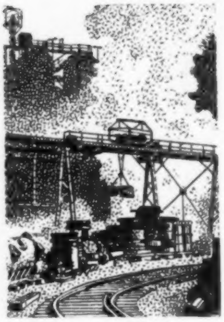
[15] "Desulphurization of Pig Iron With Pulverized Lime", by B. Kalling, C. Danielsson, and O. Dragge, *Transactions*, American Institute of Mining and Metallurgical Engineers, *Journal of Metals*, September 1951, p. 732 to 738.

[16] "Dommarfvet Process at Surhhammar Works", by S. Fornander and B. Kalling, *Transactions*, American Institute of Mining and Metallurgical Engineers, *Journal of Metals*, September 1951, p. 739-741.

[17] "A Thermodynamic Study of the Reaction $CaS + H_2O \longleftrightarrow CaO + H_2S$ and the Desulfurization of Liquid Metals with Lime", by T. Rosenqvist, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 191, *Journal of Metals*, July 1951, p. 535-540.

[18] "Effects of Manganese and Its Oxides on Desulphurization by Blast Furnace-Type Slags", by N. J. Grant, Ulf Kalling, and J. Chipman, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 191, 1951, p. 672.

Effect of MnO and SiO_2



periments was also conducted in which manganese and MnO were added during the course of the run. The rates of transfer in these experiments are shown in Fig. 13 (right). In each run the addition of MnO and Mn caused a reversal in the transfer, and at least an hour was required for the system to recover from the effects of the addition. The cause of the reversal is the MnO rather than the manganese. The oxidizing power of MnO is sufficient to reverse the progress of sulphur removal by reversing the reaction represented by equation (1) above. The normal transfer of sulphur from metal to slag is not resumed until most of the added manganese oxide has been reduced to manganese.

While these results are entirely compatible with Rocca's findings with respect to the effect of oxygen on the equilibrium, they were rather unexpected since it had not been fully appreciated that the oxygen potential corresponding to MnO was sufficient to interfere so drastically with the elimination of the sulphur from metal.

It turned out that the effect of MnO on the final equilibrium was not very great. The bulk of the manganese goes into the metal; reduction was 96% complete in the most basic and 82% in the most acid slag. The residual MnO was too small to influence the desulphurizing index, except in the most acid slag where a slight improvement in sulphur removal could be observed.

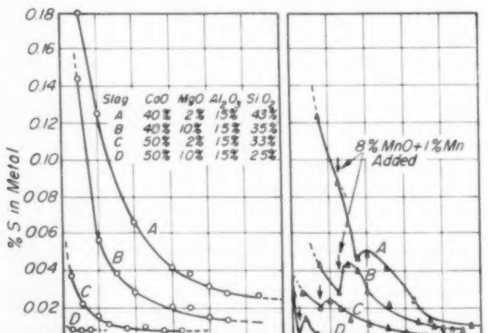
Effect of Silica on Desulphurization — The effects of MnO naturally raised the question whether other oxides exert sufficient oxygen potential to interfere in a similar manner. Specifically the question arises as to the oxidizing power of SiO_2, for it has been noted that slags higher in silica are slower in coming to equilibrium with the metal. Hatch's experiments showed that under acid slags the silicon content of the metal increased. What, then, has happened to the oxygen which originally was associated with this silicon? It has, of course, passed out of the system as carbon monoxide, but the fact that silica was reduced seems to indicate the possibility that during the process an oxygen potential exists which is higher than that conducive to rapid desulphurization.

To obtain more light on this question, a new series of experiments was conducted by Olaf Troili,[19] using the same slags and the same furnace as just described and illustrated. The silicon content of the pig iron was increased by ferrosilicon, and several experiments were run with varying initial silicon contents. The results which were obtained under a slag containing 35% SiO_2 are shown in Fig. 14. During the 9 hr. or more in which the slag and metal were in contact, there was a steady transfer of silicon from slag to metal, even when the initial charge contained as much as 4% silicon. We can infer that the pig iron which would be in equilibrium with that slag must contain considerably more than 4% silicon.

Figure 14 also notes the simultaneous transfer of sulphur from metal to slag. The slow rate of transfer in Heat 70 which had no silicon addition is considerably speeded up in Heats 82 and 84 in which a substantial addition of silicon was made. Even in the latter,

[19] "Effect of Silica Reduction on the Desulphurizing Power of Blast Furnace-Type Slags", by N. J. Grant, O. Troili, and J. Chipman, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 191, 1951, p. 672; *Journal of Metals*, August 1951.

Fig. 13 — Sulphur Removal in Apparatus of Fig. 12 From High-Carbon Metal Originally Containing 1.65% S by Blast Furnace-Type Slags at 1525° C. (2775° F.). Left: Rate without additions. Right: Rate with an addition of 8% MnO + 1% Mn (which causes a reversion of sulphur into the metal)



however, the sulphur content of the metal does not become truly constant until after about 2 hr. of contact.

These results confirm the hypothesis that the slowness of sulphur transfer is due to the concurrent reduction of silica. Apparently, if there is enough silicon in the metal to slow down the reduction of silica, as exists in Heat 84, sulphur is removed at a fairly rapid rate.

A similar set of results for a much more basic slag containing 25% SiO_2 is shown in Fig. 15. Note that the addition of about 1% silicon in the charge was sufficient to prevent reduction of silica from the slag. The desulphurization rate is also shown. In Heats 86 and 87, to which silicon was added, rate of sulphur removal has been greatly accelerated. In Heat 87, to which enough silicon was added to stop and in fact reverse the transfer of silicon, the first sample taken from the furnace had already reached equilibrium with respect to sulphur.

It is especially to be emphasized that the effect of a silicon addition in the metal is not a direct reaction with sulphur but is an indirect effect in preventing the transfer of silicon, and with it oxygen, from slag to metal. To confirm this a similar run was made using silicon-free metal and a slag consisting of lime and alumina only. The same amount of sulphur was charged as in previous experiments, and the first sample taken after the slag and metal were melted down contained no more sulphur than a sample taken 2 hr. later. In other words, this melt reached equilibrium with respect to sulphur transfer just as rapidly as those heats containing a large silicon addition.

CONCLUSIONS

The results of these experiments indicate the importance of learning something more regarding the reduction of silica from slags by carbon and by high-carbon metal. An extensive study of this problem is already under way. The results also indicate that from a practical viewpoint the control of sulphur in the making and refining of pig iron is highly dependent upon the control of oxygen. They suggest that more complete and more rapid desulphurization depends upon three factors — *(a)* the basicity of the slag, *(b)* the effectiveness of slag-metal contact, and *(c)* the oxygen potential.

One group of reactions which has been omitted from consideration in this discussion is that occurring in the openhearth between combustion gases and the charge. The steel bath picks up sulphur during melting and refining and, when high-sulphur fuel is used, this constitutes an important source of this impurity. The chemistry of the process is known in part. Chemical properties of the pure substances have been very well summarized by Richardson and Jeffes.[20] The part that is not yet known is how these substances behave when dissolved in that complex and interesting liquid which we call slag. Much careful laboratory work remains to be done before we shall have the complete answer to this question.

[20] "The Thermodynamics of Substances of Interest in Iron and Steel Making. III. Sulphides", by F. D. Richardson and J. H. E. Jeffes, *Journal*, Iron and Steel Institute, Vol. 171, 1952, p. 165.

Fig. 14 — Silicon (as Shown by Solid Lines) Continually Passes From Slag to Pig Iron, Even High-Silicon Iron, at 1525° C. (2775° F.). Sulphur (broken lines) reaches equilibrium most rapidly in highest silicon metal. Slag is Slag B of Fig. 13: 40% CaO, 10% MgO, 15% Al_2O_3 and 35% SiO_2

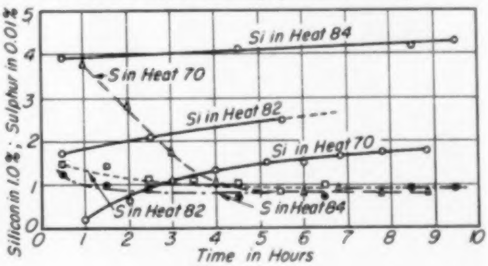
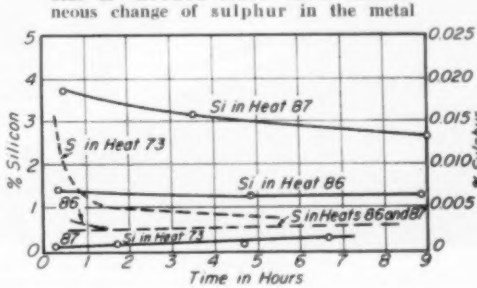
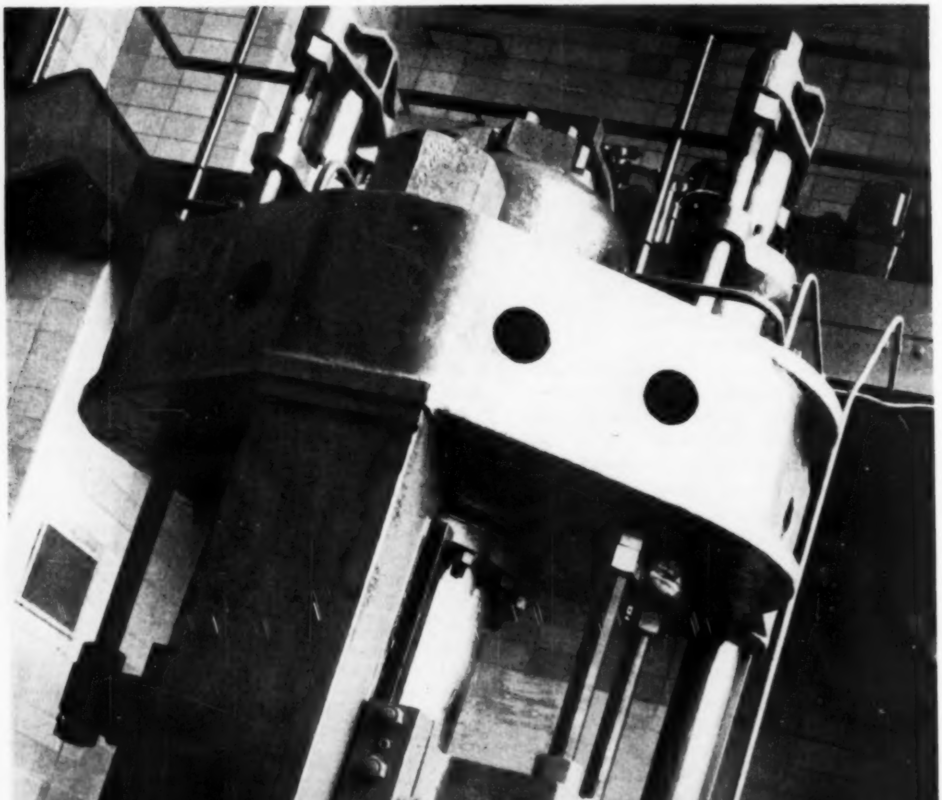


Fig. 15 — Solid Lines Show Change With Time in the Silicon Content of Pig Iron in Contact With Slag D of Fig. 13 (50% CaO, 10% MgO, 15% Al_2O_3 and 25% SiO_2) at 1525° C. Broken lines show simultaneous change of sulphur in the metal





Experimental Operations Using a Metal Powder Compacting Press.
Courtesy Firth Sterling Steel Co.

By John P. Lyle, Jr., Research Engineer, Aluminum Research Laboratories, New Kensington, Pa.

Excellent Products of Aluminum Powder Metallurgy

FROM TIME TO TIME since 1948, references to an alloy produced from aluminum powder have appeared in the metallurgical literature.* This alloy, which was designated "SAP", was developed by Aluminium Industrie Aktiengesellschaft (A.I.A.G.). The material apparently had many unusual properties, the most important of which are strength, stability, and resistance to creep at elevated temperatures.

Following tests on samples supplied by A.I.A.G. in 1949, a considerable amount of work has been carried out by Aluminum Co. of America in this field of powder metallurgy. The object of this short article is to report on the properties of extrusions produced from aluminum powders.

Extrusions have been manufactured from several lots of unalloyed powders, the aluminum purity of which was 98.8% or higher. The powders varied in three important respects, namely, particle size, particle shape, and oxide content. It was found that the extrusions had a wide range of properties, depending to a large degree upon the powders from which they were fabricated. One cannot say at this time which of the three variables named above is the predominating one; in fact, they are related to one another to a certain extent. For example, a decrease in particle size is accompanied by an increase in oxide content. In the discussion which follows, the properties are sometimes related to oxide content; the reason this relationship is used (rather than the one between properties and particle size or shape) is that oxide content is much easier to determine and describe.

In Fig. 1, 2 and 3 certain properties of extrusions are plotted as a function of the oxide content. While most of the data in these figures were obtained from samples fabricated by Alcoa, several points for samples supplied by A.I.A.G. are included. As would be expected, the electrical conductivity decreases as oxide content increases (Fig. 1), and the coefficient of thermal expansion decreases in a similar manner. The tensile strength and yield strength, however, increase with oxide content. The tensile strengths in the neighborhood of 60,000 psi. and yield strengths of around 40,000 psi., shown on the right-hand side of Fig. 2, are very impressive, particularly in view of the fact that the powder was unalloyed aluminum. The elongation, of course, decreases with oxide content. Oxide affects the tensile properties at 600° F. (Fig. 3) in about the same way as at room temperature, but the properties of the materials made from powders are

*"The Sintering of Aluminum Alloys", by A. von Zeerleder, *Zeitschrift für Metallkunde*, Vol. 41, August 1950, p. 228 to 231.

"Heat Resisting Sintered Aluminum", by R. Irmann, *Revue de l'Aluminium*, Vol. 28, July-August 1951, p. 269 to 275, and September 1951, p. 311 to 316.

"Sintered Aluminum of High-Temperature Strength", by Roland Irmann, *Aluminium*, Vol. 27, October 1951, p. 29 to 36.

"Investigations on Sintered Aluminum", by Edith Boenish and Wilhelm Widerholt, *Zeitschrift für Metallkunde*, Vol. 42, November 1951, p. 344 to 348.

"Sintered Aluminium Powder", *Metal Industry*, Vol. 81, Aug. 22, 1952, p. 143 to 146.

"S.A.P., a New Material Made From Aluminum Powder Sintered Hot", by A. von Zeerleder, *Metaux: Corrosion — Industries*, Vol. 27, June 1952, p. 274 to 277.

"Sintered Aluminium With High Strength at Elevated Temperatures", by R. Irmann, *Metallurgia*, Vol. 46, September 1952, p. 125.

Swiss Patents No. 250,118 and 259,878.

When powder metallurgical fabrication methods are applied to aluminum, some unexpected things are found. Oxide on the particles is not the handicap in compacting and sintering which it is on other commercial powders. Extruded bars originating in powdered aluminum (unalloyed but with high content of oxide) have tensile properties more appropriate to alloyed aluminum forgings, and may possibly extend the present limits for high-temperature service by as much as 300° F.

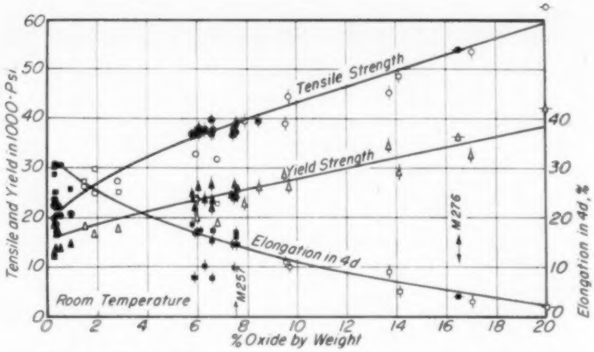


Fig. 2 — Tensile Properties of Aluminum Extrusions at Room Temperature as a Function of Oxide Content. For comparison, A.M.S. specification 4154C covering aluminum alloy 75S-T6 extrusions in 1-in. size — one of the best of the commercial alloys — requires 80,000 psi. min. tensile strength, 72,000 psi. min. yield strength, 7% min. elongation in 4 d. (See Fig. 3 on opposite page for legend identifying points)

even more impressive than they are at room temperature relative to the wrought aluminum alloys on the market today. (In Fig. 3, the data represent properties after 100 hr. at temperature.)

After considering the general range of properties available, a material containing 7.8% oxide (designated M257) and one containing 16.5% oxide (designated M276) were chosen for more extensive tests. Their tensile strengths are plotted against test temperature at the left of Fig. 4 with two commercial alloys, 32S-T6 and XF18S-T61, for comparison. Alloy XF18S-T61 was chosen because it ranks high among commercial aluminum alloys in tensile, creep, and fatigue properties at 400 to 600° F. The other alloy, 32S-T6, was chosen because it is widely used for aircraft and diesel pistons which operate at moderately high temperatures. It will be noted that 100 hr. at temperature is specified for the two commercial alloys in Fig. 4, but that none is specified for M257 and M276. It is necessary to specify time for XF18S-T61 and 32S-T6 because tensile strengths of these alloys decrease with time at temperature. On the other hand, the tensile strengths of M257 and M276 are independent of time at temperature.

Fig. 1 — Electrical Conductivity and Thermal Expansion of Aluminum Extrusions Vary Inversely With the Oxide Content. 100% on vertical ordinate at left represents conductivity at 25° C. of International Standard for Copper. Vertical ordinate at right is average coefficient of thermal expansion $\times 10^{-6}$ per °C. for the range 20 to 100° C., measured in a longitudinal direction

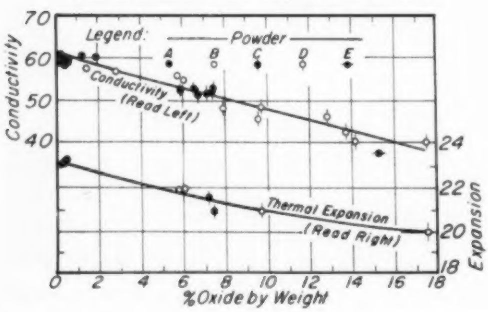


Figure 4 shows that strength of M257 is superior to XF18S-T61 above 525° F. and to 32S-T6 above 450° F. if the points where the curves cross are taken as the criteria. The range of superiority of M276 is even greater than that of M257 because M276 crosses XF18S-T61 at 420° F. and 32S-T6 at some temperature below 400° F. Another way to compare these alloys is to say that M257 has as high a tensile strength at 900° F. as XF18S-T61 has at 600° F. and as 32S-T6 has at 550° F.

The yield strengths of these four materials are also compared at the right of Fig. 4. Here again, the time at temperature prior to testing is stated for the conventional alloys, but not for the powder metallurgy products. If the crossing points of the curves are taken as the criteria, M257 is superior to XF18S-T61 above 510° F. and to 32S-T6 above 450° F. Likewise, M276 is superior to XF18S-T61 above 425° F. and to 32S-T6 above some temperature below 400° F. Stated another way, M257 has as high a yield strength at 900° F. as XF18S-T61 has at 580° F. and 32S-T6 at 515° F.

No plot of elongation versus temperature has been made. M257 and M276 are different from conventional alloys in that the elongation decreases rather than increases with increasing test temperatures. The elongation of M257 falls from 13% at 600° F. to 5% at 800° F. and 3% at 1000° F., and the elonga-

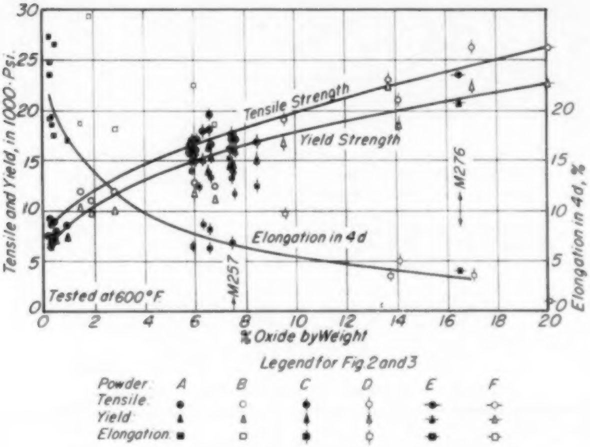


Fig. 3 — Surprisingly Good Results of Short-Time Tensile Tests at 600° F., the Test Pieces Having Been Held at Temperature for 100 Hr. Before Testing. See Fig. 4 for comparison with commercial alloys. In both Fig. 2 and 3 the yield strength is measured at 0.2% offset

be at a temperature of about 500° F.

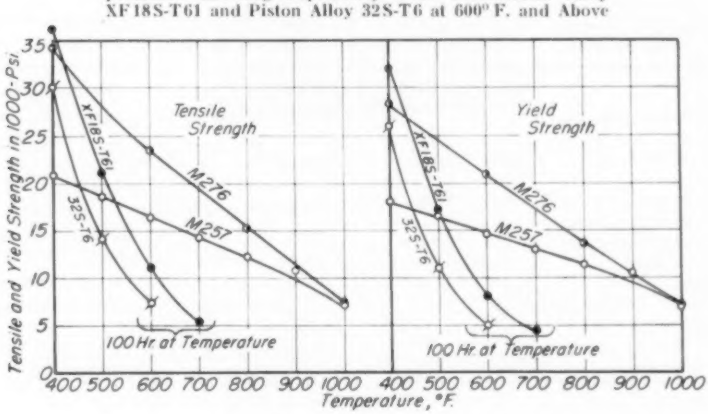
Figure 5 shows the results of fatigue tests on M257 at 400, 500, and 600° F., and comparison curves for XF18S-T61. It will be noted that temperature has very little effect upon the fatigue strength of the extruded compact when tested in the 400 to 600° F. range — in fact, there is not enough difference to justify drawing separate curves. For this reason, all points have been included within one band for M257. It will also be noted that XF18S-T61 is superior to M257 at 400 and 500° F., and even at 600° F. up to about 40 million repetitions of stress. For larger numbers of cycles at 600° F., there is no significant difference between XF18S-T61 and M257.

From the trends indicated by the curves in Fig. 5, it is expected that M257 will compare more favorably with XF18S-T61 at temperatures above 600° F., inasmuch as tensile tests show that M257 loses in static strength much less than XF18S-T61 as the temperature is increased.

tion of M276 falls from 4% at 600° F. to 2% at 800° F. and 1% at 1000° F.

The results of creep tests on M257 at 400, 500, and 600° F. are shown in Table I. Alloy XF18S-T61 is included for comparison at 400 and 600° F. Note that M257 is clearly inferior to XF18S-T61 at 400° F., but that the positions are inverted at 600° F. The crossover point where M257 becomes superior to XF18S-T61 in creep resistance cannot be fixed with any accuracy, but it appears to

Fig. 4 — Short-Time Tensile Strengths (Left) and Yield Strengths at 0.2% Offset for M257 Extrusion With 7.8% Oxide and M276 Extrusion With 16.5% Oxide at Various Temperatures Showing Superiority Over Commercial Alloy XF18S-T61 and Piston Alloy 32S-T6 at 600° F. and Above



Aluminum Powders

Most of the emphasis so far has been on the high-strength alloys in this series. The materials containing small amounts of oxide should not be ignored, however, because they also have interesting properties. For example, the alloy containing about 0.5% oxide has a good combination of electrical conductivity and resistance to creep. The properties of this material, which has been designated M255, are compared with those of EC-H18 in Table II; M255 has slightly lower electrical conductivity at room temperature but has much higher resistance to creep at 300° F. than EC-H18.

At the present time, the aluminum powder metallurgy products M255, M257, and M276 are being produced only on an experimental scale for determination of their properties and for trial in specific applications.

Summary — Materials having a wide range of properties can be made by extruding unalloyed aluminum powders. One alloy in this series, M255, containing about 0.5% oxide, has a good combination of electrical conductivity and resistance to creep at 300° F., which may make it suitable for applications requiring good conductivity and resistance to creep at moderately elevated temperatures. Examples of such possibilities are bus bars, certain types of fuses, rotor windings, and conductor terminals and fittings. Another alloy in the series, M257, containing about 7.8% oxide, begins to show superiority in strength over the best of the commercial wrought aluminum alloys at approximately 500° F. and this superiority increases as the temperature increases. This alloy may raise the maximum useful temperature for aluminum as much as 300° F. Data for a third alloy, M276, containing 16.5% oxide, are not as complete as for M257, but on the basis of tensile tests it is even stronger than M257. These two alloys are being considered for various engine applications, such as diesel and aircraft pistons, valves to control the flow of hot gases, and compressor blades and disks for gas turbines.

For the present, production of alloys M255, M257, and M276 is limited to experimental quantities.

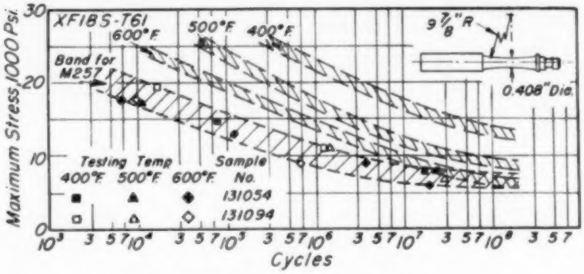


Fig. 5 — Cantilever-Beam Fatigue Tests on Two ¾-In. Extruded Rods of M257 (7.8% Oxide) at Elevated Temperatures, With Comparison Tests on a Forged Bar of XF18S-T61

Table I — Comparative Creep Characteristics

	M257			XF18S-T61	
	400° F.	500° F.	600° F.	400° F.	600° F.
Stress to cause creep rate of					
0.00001 in./in./hr.	16,000	13,000	10,500	25,500	—
0.0001 in./in./hr.	17,000	14,000	11,500	29,000	—
0.001 in./in./hr.	17,500	14,500	12,500	32,500	6,000
0.01 in./in./hr.	—	—	—	—	8,000
Stress to cause failure in					
1 hr.	—	—	—	—	9,500
10 hr.	18,000	15,000	12,500	31,000	7,000
100 hr.	17,000	14,000	11,500	27,000	—
1000 hr.	16,000	13,000	10,500	24,000	—

Table II — Properties of M255 (0.5% Oxide) and EC-H18

Properties	M255	EC-H18
Tested at Room Temperature		
Tensile strength, psi.	22,600	22,800
Yield strength, 0.2% offset, psi.	17,600	20,500
Elongation in 4 d	22%	16%
Electrical conductivity	59%	61%
Tested at 300° F.		
Tensile strength after 1000 hr., psi.	15,400	16,200*
Yield strength, 0.2% offset, after 1000 hr., psi.	13,600	14,300*
Elongation in 4 d after 1000 hr.	22%	17%*
Stress for minimum creep rate of:		
0.000001 in./in./hr., psi.	9,500	4,500
0.00001 in./in./hr., psi.	10,500	8,000

*Estimated from EC-H19.

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

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Extra-Low-Carbon STAINLESS STEEL

New Type Chromium-Nickel Steels Have Added Corrosion Resistance

New and improved austenitic stainless steels of the 18-8 type have been developed which have superior corrosion resistance after being exposed to heat. These steels, known as extra-low-carbon stainless steels, were designed especially for use in welded and stress-relieved equipment that is exposed to more severe corrosive conditions than are normally encountered by other types of straight 18-8 stainless steel.

Under severe corrosive conditions, intergranular attack may occur in some of the higher carbon grades of austenitic stainless steels that have been subjected to the temperature range of 800 to 1600 deg. F. during welding or hot forming operations. It is generally agreed that this type of corrosion is caused by complex carbides that are formed at the grain boundaries of the stainless steel during heating.

The effect of heat is rarely harmful in the ordinary fabrication of stainless steel for most applications, such as in architecture, the food and dairy industries, in hospitals, and in the home. However, in the chemical and other allied industries, where stainless steel is used in the handling of very corrosive chemicals, these new extra-low-carbon stainless steels should most certainly find wide use.

In general, there are three ways in which the precipitation of carbides can be controlled in stainless steel:

1. Heat-treating so that the carbides present are dissolved.
2. Alloying with an element, such as columbium, tantalum, or titanium, that will tie up the carbon in the form of a harmless carbide.
3. Decreasing the carbon content of the steel.

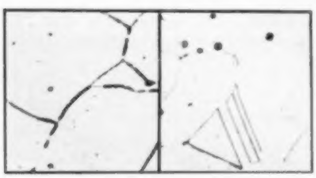


Fig. 1 Left: Carbide precipitation at the grain boundaries of an 18-8 stainless steel, containing 0.059 per cent carbon, after being held at 1200 deg. F. for 1 hour. Right: Absence of carbide precipitation in 18-8 stainless steel of 0.03 maximum carbon content, after being held at 1200 deg. F. for the same length of time.

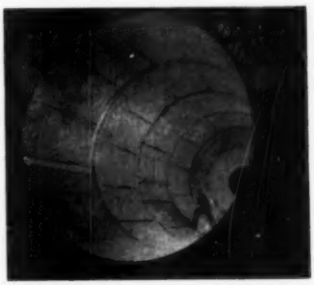


Fig. 2. The new extra-low-carbon stainless steels are especially suited for large types of process equipment, such as this fractionating tower. They require no heat-treatment after welding.

Heat-Treatment After Welding

Before the development of extra-low-carbon stainless steel, or of the "stabilized grades," one means for preventing intergranular corrosion was to heat-treat stainless steel that had been subjected to the dangerous temperature range, so that the precipitated chromium-carbides would go back into solid solution. It was found that when a welded part was heated to temperatures of 1950 to 2000 deg. F., and then cooled rapidly, most of the carbides were retained in solid solution. This extra heat-treatment is sometimes impractical, however, because of the design or massive size of some types of welded equipment.

Decreasing Carbon Content

A recent development in preventing intergranular corrosion has been the extra-low-carbon stainless steels. To be substantially harmless in stainless steel for as-welded or welded and stress relieved chemical equipment operating at temperatures under 700 deg. F., carbon must not be present in quantities over 0.03 per cent.

In 1937, ferrochrome with 0.03 per cent maximum carbon was first produced for the steel industry by ELECTROMET. This product has helped make it possible to produce very-low-carbon stainless steels—steels that are completely immune to intergranular corrosion after welding or after subjection to a stress-relieving heat-treatment.

The amount of stabilizing element that is necessary to "fix" carbon in stainless steel is in direct proportion to the carbon content of the steel. Therefore, the lower the carbon the less is the amount of stabilizing element required. Lowering the carbon content is an efficient means of conserving columbium, tantalum, and titanium.

Metallurgical Service Available

If you use welded stainless steel equipment, it will pay you to investigate the advantages of using extra-low-carbon steels. If you produce stainless steel, our metallurgists will be glad to give you technical assistance in the use of ferrochrome of 0.03 per cent maximum carbon. For further information, write to the nearest ELECTROMET office.

For a more detailed account of the properties of extra-low-carbon stainless steel, write for a free copy of the technical paper, "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content".

Correspondence

Sublimation Crystals of Molybdenum

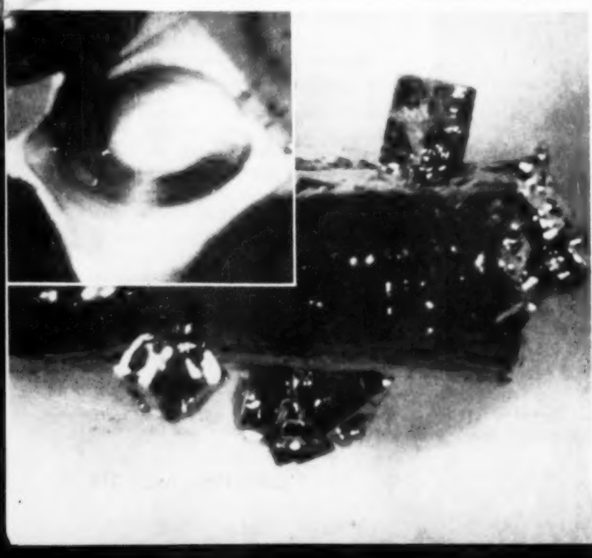
BALTIMORE, MD.

Crystals up to $\frac{1}{16}$ in. in maximum dimension were deposited on a high-purity molybdenum rod ($\frac{1}{8}$-in. diameter) while the rod was being heated in vacuum by its own resistance. This rod is so heated in order to convert it into a single crystal, as described in "Growth of Molybdenum Single Crystals" by Chen, Maddin and Pond, *Journal of Metals*, Vol. 191, p. 461-464. The peculiar conditions for handling these rods as well as the material are probably responsible for their growth; however, the mechanism which may be involved in this growth has not been determined (Fig. 1).

The crystals assumed either the cube and octohedral or dodecahedral form. Generally each face had a depression in its center. The walls of the depression were stepped to give the appearance of several different layers of the same crystal face being exposed (see inset). Each crystal was attached to a thin stem.

ROBERT B. POND
Assistant Professor
Johns Hopkins University

Fig. 1 — Sublimation Crystals of Molybdenum Deposited on a Molybdenum Rod of High Purity. Inset shows nature of depression occurring on each face of crystal



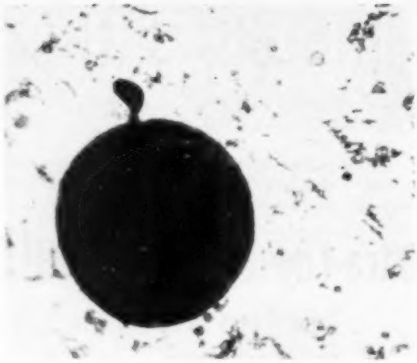


Fig. 2 — Cross Section of "Ruptured" Inclusion Formed in Weld Deposit

Mineral or Vegetable?

TOWSON, MD.

Here is a photograph of an inclusion which was found in an E7011 weld deposit, its claim to distinction being the "sprout" which appears at the top (Fig. 2). Even though this may be a relatively common occurrence, there is literally one chance in a million of the cross section being made through this feature.

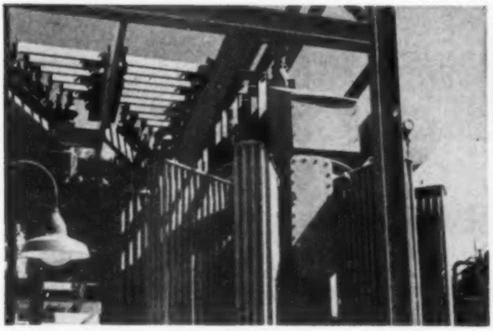
Cause for the formation of this sprout can perhaps be explained as follows: When the weld metal was deposited, both the metal and the inclusion were molten and the inclusion was spherical in shape. As the mass cooled, the inclusion froze on the outside surface, with the inside remaining molten. With continued cooling, shrinkage of the solidified surface of the inclusion was greater than that of the molten center. The pressure inside the inclusion built up to the point where the outer surface, or skin, was ruptured and an offshoot was formed to relieve the internal pressure — the metal was still molten when this was formed. Further cooling, then, had no more effect on the form of the inclusion.

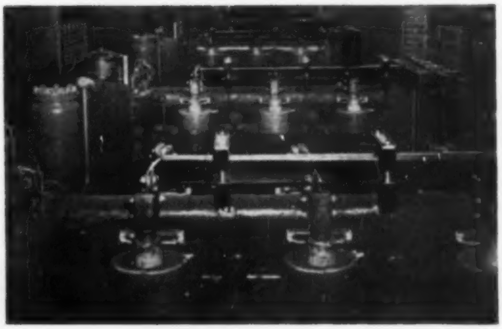
When the microsection was made, the writer was fortunate enough to happen on that one chance in a million, and to get the section as shown. The cross section of this inclusion is shown at 1500 ×.

H. L. SITTLER
Metallurgist
Arcrods Corp.

(*Continued on p. 116*)

It takes a Lot of Copper to make a Lot of Chemicals!





These photographs show a lot of copper bus bar in a new plant of a great chemical company, whose name and location cannot be disclosed. The copper carries heavy currents to electro-chemical equipment for the production of valuable products used in national defense and in industry. Revere furnished 325,000 pounds of bus bar for this service, the bar going into substations, rectifier stations, and cell houses. In addition, at the time of installation the Revere Technical Advisory Service collaborated with the customer in working out some difficult details in the design of switches. If you need electrical conductors, remember that copper has the highest electrical conductivity of all the commercial metals, that Revere makes bus bar, and that the Revere Technical Advisory Service is always ready to work with you on any problem concerning copper and its alloys or aluminum alloys. Call the nearest Revere Sales Office.

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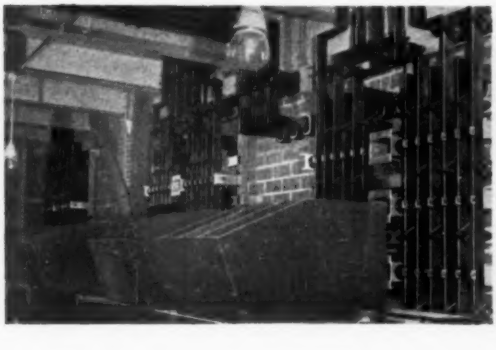

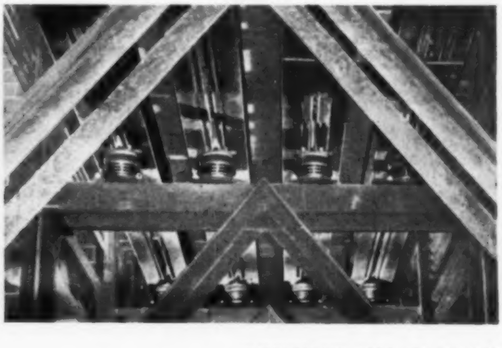

Grain Refinement of Titanium

URBANA, ILL.

The transformation in crystal structure of titanium from close-packed hexagonal to body-centered cubic raises the question whether grain size changes take place during the heating and cooling cycles through the transformation. The technical literature does not specifically refer to changes in grain size. Replies to inquiries to the principal producers of the metal indicate that such changes are expected, but no direct observation and proof had been established. A simple experiment, utilizing vacuum etching techniques, shows that grain refinement does occur in the beta-to-alpha transformation; this further indicates that the transformation is by the normal nucleation and growth process.

Vacuum etching of titanium takes place at elevated temperatures, provided one end of the evacuated tube holding the specimen is at a lower temperature than the portion containing the specimen. The temperature differential provides a condenser effect and permits condensation of titanium evaporating from the heated specimen. Heating in an evacuated tube which receives uniform radiation does not produce etching.

Three specimens, which had been cold rolled to 15, 30 and 38% deformation, were placed in evacuated Vycor tubes and given the following heat treatment:

1. Heated at 1427° F. (775° C.) for 10^5 sec. to establish a grain size.
2. Heated to 1697° F. (925° C.), vacuum etched and cooled to room temperature.

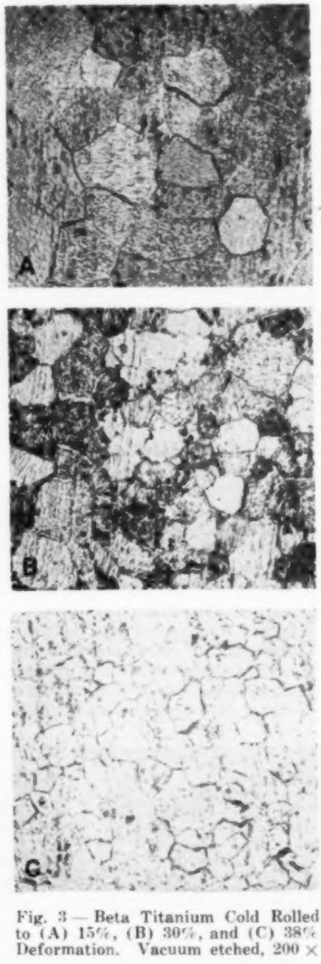

Fig. 3 — Beta Titanium Cold Rolled to (A) 15%, (B) 30%, and (C) 38% Deformation. Vacuum etched, 200 ×

The vacuum etching outlined the beta grains that had existed at the higher temperature and permitted a

(Continued on p. 118)

Correspondence

(Continued from p. 116)

grain size determination. The vacuum-etched structures are shown at 200 × in Fig. 3. The specimens were sectioned and the alpha grain size was determined by the usual metallographic methods.

The results of the grain size determinations were found to be:

	Grain Size in Mm. Diameter		
Deformation	15%	30%	38%
Grain size before cold rolling	0.0108	0.0108	0.0108
Grain size after annealing 10^5 sec. at 775° C.	0.0307	0.0211	0.0167
Beta grain size at 925° C.	0.0389	0.0200	0.0171
Final grain size at room temperature	0.0243	0.0171	0.0145

These data demonstrate that grain size changes do take place during the crystallographic transformation.

H. P. Leighly
Olin Industries Fellow
H. L. Walker
Head of Department
College of Mining and Metallurgical Engineering
University of Illinois

Retained Austenite in Carburized Alloy Steels

Kalamazoo, Mich.

The retention of austenite, resulting from an incomplete transformation of the austenite-martensite reaction, is usually associated with a quenching rate which is too rapid. However, this reverse is true in many instances.

Heavy sections — such as transmission spline shafts made from A.I.S.I. 8620 — carburized with an effective case depth of 0.050 in. and quenched direct from the carburizing temperature can be hardened in oil to produce either large or small amounts of retained austenite, depending on the rate of quenching. Thus, a quench in still oil can give more retained austenite than a quench in fast oil.

It has been observed that even the straight carbon steels (small sections of C1117 or C1118) are not immune. A quench direct from the carburizing temperature in oil retains more austenite than the faster water quench. The low hardness produced with an oil quench can be improved with a cold treatment. This increase in hardness bears out the presence of retained austenite.

(Continued on p. 120)

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Correspondence

(Continued from p. 118)

Very often, parts that give a low Rockwell reading after carburizing are requenched because of the belief that the quenching rate was too slow to produce a fully martensitic structure, and in a measure this is true. A change to a faster oil quench, or even a water quench, produces the full hardness desired. However, in many instances, the cause is retained austenite rather than the higher transformation products of a slow quench. Despite this there is always the very real possibility that a quenching rate can be below the critical cooling rate, in which circumstance low hardness will be caused by the formation of higher transformation products.

The statements set forth above seem to hold true especially for the heavily carburized cases rich in carbon, and with a direct quench from the carburizing temperature.

W. J. JABSEN
Metallurgical Engineer
Kalamazoo Steel Process Co.

Accidental Hyper-Graphitization

CLEVELAND

Recently we encountered a metallic "inclusion" while machining a rod of 4-in. diameter graphite. The "inclusion" was a ¾-in. hexagonal nut which had somehow fallen into the coke-flour mix, and went through the several weeks' graphitizing cycle at 4000° F. The iron, of course, became molten and saturated with carbon at this high temperature. Enclosed as it was in a carbon mold, the nut retained its shape quite perfectly (Fig. 4), even to the sharp detail of the threads.

The photograph at normal size shows how the pro-eutectic graphite flakes grew to tremendous size during the extremely slow cooling while solidifying at the end of the graphitizing cycle. The photomicrograph at 25 × gives some idea of the structure of this high-carbon alloy. Huge

(Continued on p. 122)

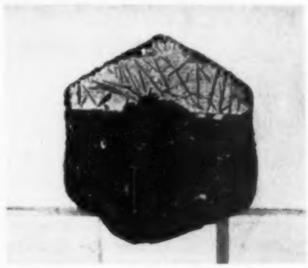
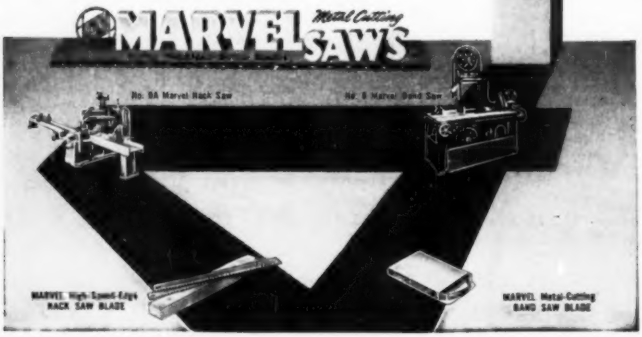


Fig. 4 — Graphitized Nut at Normal Size With Portion Polished to Show Size of Graphite Flakes

Fig. 5 — Structure of the Graphitized Nut. Nital etch, 25 ×



Correspondence

(Continued from p. 120)

pro-eutectic graphite flakes, normal coarse graphite flakes, and fragments of ungraphitized carbide are seen in a matrix of pearlite. Under polarized light it was observed that at least some of the immense graphite flakes have grown as single crystals from the high-carbon melt. While an exact carbon analysis is difficult because of the problem of sampling, the total carbon of the piece runs about 5.9%.

CHARLES H. JUNGE
Metallurgical Staff
Cleveland Graphite Bronze Co.

More on Hazardous Etchants

WILMINGTON, DEL.

A letter by L. H. Satz was published in the August issue of *Metal Progress* which warned of danger of allowing an etchant consisting of 20 ml. HF, 10 ml. HNO_3, and 30 ml. of glycerol to remain standing for periods longer than 3 to 4 hr. It should be pointed out that the same hazards exist with the use of an etchant consisting of 20 to 30 ml. HCl, 10 ml. HNO_3, and 30 ml. glycerol.

Upon two occasions when this reagent was left standing in glass etching dishes for periods longer than 2 to 3 hr., a violent reaction occurred which produced large quantities of NO_2 and a fine spray of acid. As a precaution, this etchant should be discarded promptly after use and never be stored in stoppered containers.

DONALD WARREN
Engineering Research Laboratory
Materials of Construction Section
E. I. du Pont de Nemours & Co.

Comment on High Yield of Weld Metal

SWANSEA, ENGLAND

With reference to Mr. Huseby's communication "High Yield of Weld Metal" in *Metal Progress*, May, p. 96, and to the suggestion that the high yield is due to precipitation of solute carbides, the following quotation may be of interest. It refers to experiments of the late Dr. Swinden and his colleagues "on steels with 0.25% of carbon, normal manganese and silicon, and titanium increasing from nil to 1.6%".

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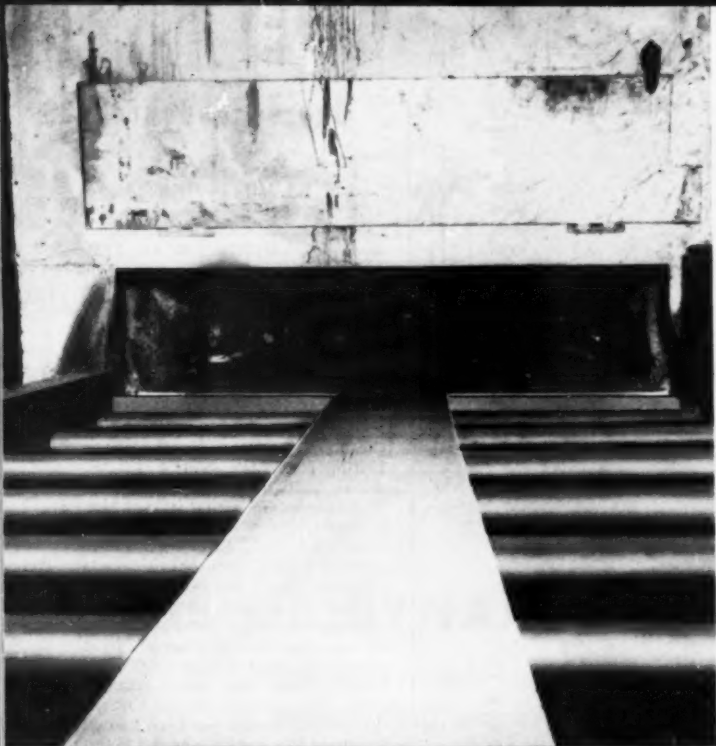

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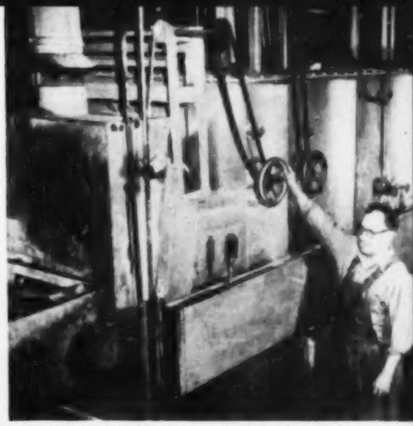

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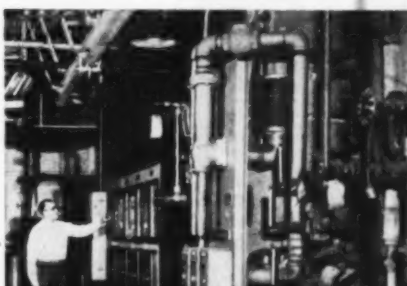

G-E ATMOSPHERE equipment like this Neutralene gas producer provides unvarying furnace atmosphere of high purity—either rich or lean.

Correspondence

(Continued from p. 122)

"On quenching from 950° C. (1740° F.) the hardnesses for that series of steels, with titanium respectively nil, 0.41, 0.76, 1.05, and 1.6%, were 413, 233, 209, 198, and 111. On going up to a higher temperature, 1250° C. (2280° F.), the hardness values were respectively 364, 385, 308, 328, and 233, and therefore if one soaked the steel for a sufficiently long time at a high temperature one could get really high hardness values." This passage is taken from the *Journal* of the Iron and Steel Institute, Vol. 142, 1940, p. 225-226, where further references are given.

Swinden ascribed these high hardnesses, including those steels in which the whole carbon must have been in the TiC form (Ti to C ratio of 4.2 to 6.4), to the relatively inert carbides being taken into solution at high temperatures. Naturally, steels of this class will be relatively hard after rapid cooling from 1250° C. or over, without any aftertreatment. Thus, although precipitation hardening in 18-8-Cb steel has been known for about 10 years (Wever and Peter, *Archiv für das Eisenhüttenwesen*, Vol. 33, 1941-42), Swinden's observations on entirely different and relatively simple materials provide a kind of cross-evidence in support of the carbide-solution theory.

The value of the elastic modulus quoted by Mr. Huseby for his stress-relief heat treated weld metal is, I believe, extremely low (21,500,000 psi.). On general grounds, one would expect a precipitation treatment to increase the modulus in a similar way as does heating after cold working (see, for example, *Metal Progress*, May 1937, p. 48-49).

N. H. POLAKOWSKI
University College

Welcomes Comment on High Yield of Weld Metal

MILWAUKEE

The correspondence from Mr. Polakowski was very welcome and provides another illustration of the relative solubility of the carbides of titanium.

It is our opinion that the low Young's modulus reported for the Type 347 weld deposit is due to the deposited metal acquiring preferential orientation. The markedly elliptical shaped fracture of austenitic all-weld tensile specimens is an indication of this directionality. The

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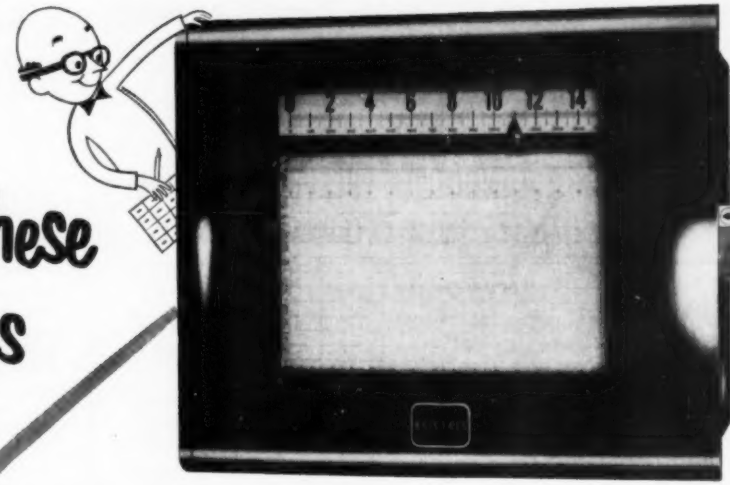

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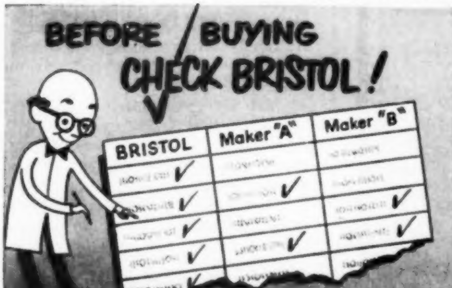

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Correspondence

(Continued from p. 124)

modulus for pure single crystals of body-centered cubic iron (as given in *Metals Handbook*, p. 430) varies according to crystallographic direction as follows: 18.9 million psi. for [100], 31.3 million psi. for [110], and 40 million psi. for [111]. Polycrystalline pure iron, of course, shows the normal modulus of 30 million psi.

Yield strength which is higher and Young's modulus which is lower than the corresponding wrought analysis is generally shown for austenitic all-weld tensile bars tested in the longitudinal direction of the weld. As previously stated, we believe the phenomena to be due to precipitation and anisotropy.

R. A. Huseby
Metallurgical Research
A. O. Smith Corp.

Zinc Stocks Are Ample

New York

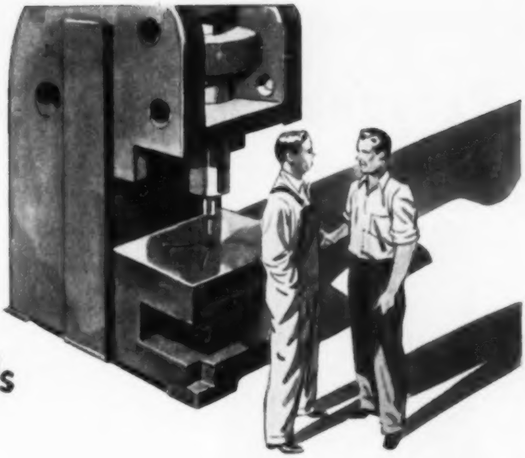
I have recently returned from an extensive trip during which I talked to many engineers and designers in a wide variety of industries. Previous to my trip I had been under the impression that engineers were aware that government restrictions limiting the uses of zinc had been removed, and that now the supply of zinc is entirely adequate. To my surprise, I found that they thought there was a shortage of zinc and its use was still under control.

The American Zinc Institute has assured us that the improved production and supply situation is not temporary and have so stated in their publication, "More Facts About Zinc". Because of the confusion in the minds of so many engineers who must decide which metal or alloy should be used in new products, it might be timely to repeat some of the facts issued by the institute:

Zinc is no longer classified as a critical and scarce material, and the Government is making no regular purchases of zinc for the national stockpile. The National Production Authority released zinc from allocation, delivery and use controls on May 15, 1952.

Slab zinc production in the first seven months of 1952 exceeded 1951 production in the same period by 20,000 tons. Stocks of slab zinc at smelters on July 31 were 97,000 tons as compared to 22,000 tons on Jan. 1, 1952. Price of slab zinc is very much lower than at Jan. 1.

C. R. Maxon
Market Development Div.
New Jersey Zinc Co.



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Personal Mention

Frank N. Speller

Frank N. Speller ⊕ recently became an associate member of Management Counselors, Inc., New York, business consultants, and will serve principally as a consultant on problems of corrosion, a field in which he is world famous for his extensive investigations. He is the author of many technical papers, mainly in the field of corrosion and metal protection. His book, "Corrosion — Causes and Prevention", is now in its third international edition. Dr. Speller was born in Toronto, Ontario, Canada, on January 1, 1875. He graduated from the University of Toronto with a Bachelor of Applied Science degree in 1894. After graduation he was awarded a fellowship at the University and then went to Pittsburgh to work in the chemical laboratory of the Carnegie-Illinois Steel Corp., Homestead, where he later became assistant metallurgical engineer of the National Tube Co. in McKeesport. In 1904 he was made metallurgical engineer of National Tube in Pittsburgh, in which capacity he served until 1926. He was then promoted to director of the metallurgical and research department of National Tube, a position he held until 1940 when he went into private consulting work. He has been recognized for his achievements by the award of an honorary D.Sc. degree from the University of Toronto in 1923, the Longstreth Medal of the Franklin Institute in 1927, the Medal of the American Iron and Steel Institute in 1931, an honorary membership in the American Society for Testing Materials in 1946, and the Frank Newman Speller Award in Corrosion Engineering, presented to him in 1947 by the National Association of Corrosion Engineers. In 1934 he delivered the annual Howe Memorial Lecture of the American Institute of Mining and Metallurgical Engineers.

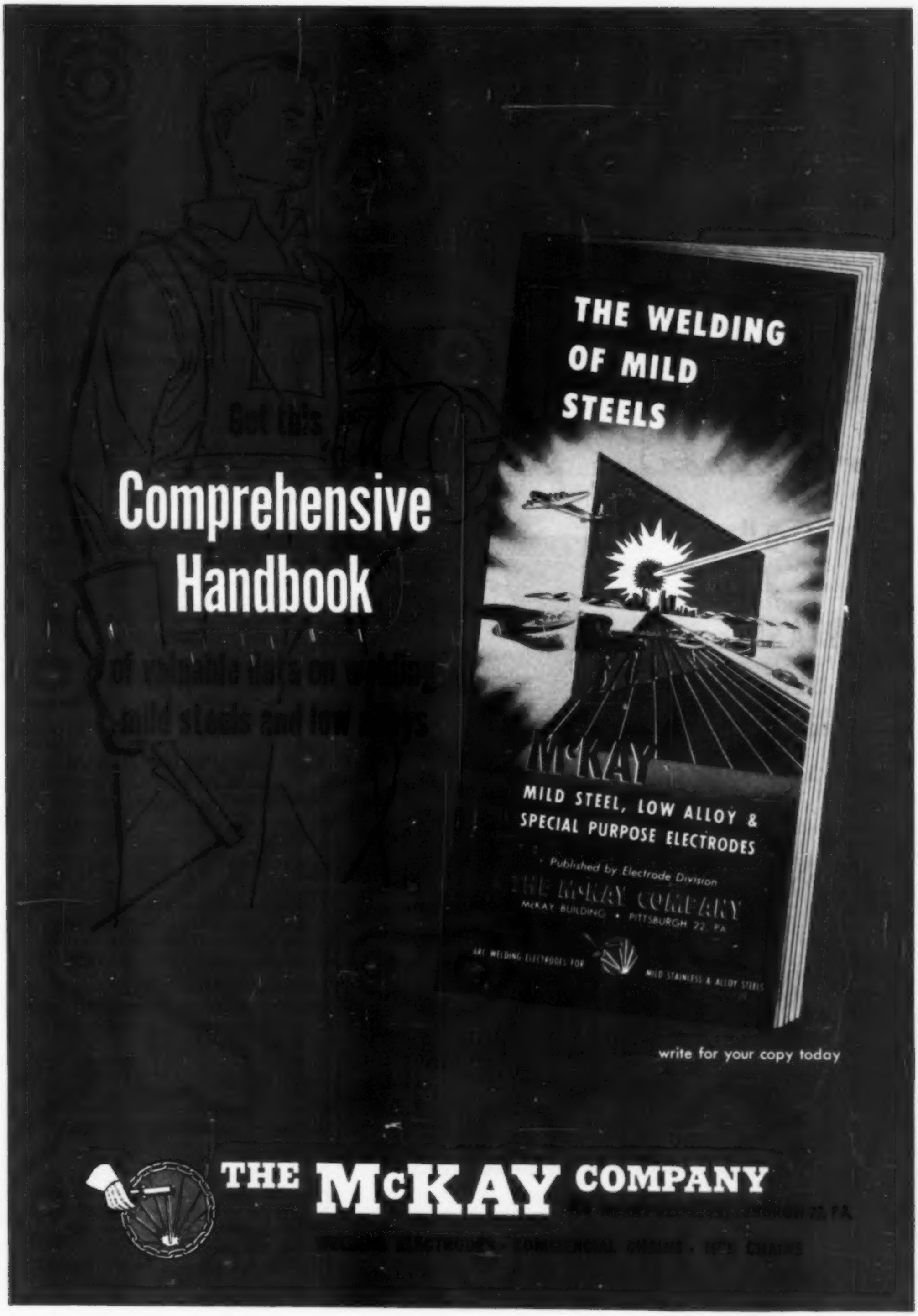
Tien-Shih Liu ⊕ and **Harry F. Ross** ⊕ have joined the staff of Horizons Inc., Cleveland. Dr. Liu, formerly a teaching fellow at Notre Dame University where he was in charge of the undergraduate metallographic laboratory, is senior research associate in the metallurgy department. Mr. Ross is now research supervisor in the same department. He was formerly associated with Battelle Memorial Institute.

Fred L. Plummer ⊕, director of engineering, Hammond Iron Works, Warren, Pa., was elected president of the American Welding Society for 1952-53 and took office during the annual meeting of the Society in October at Philadelphia. He has been with Hammond Iron Works since 1940 and is also general manager, Hammond Latino Americana, a construction company operating outside the continental United States. **Eric R. Seabloom** ⊕, supervisor of field engineering, Crane Co., Chicago, was elected first vice-president in the national headquarters. The new vice-president of the Middle Eastern District is **Donald B. Howard** ⊕, metallurgist at American Car & Foundry Co., Berwick, Pa. **John H. Blankenbuehler** ⊕, design engineer, Hobart Bros. Co., Troy, Ohio, is the new vice-president of the Central District.

W. P. Fitz-Randolph ⊕, formerly technical sales and service director for Heatbath Corp., Springfield, Mass., has been appointed New England sales engineer for Ipsen Industries, Inc., Rockford, Ill.

Amos J. Shaler

Dr. Amos J. Shaler has been appointed professor of metallurgy and chief of the division of metallurgy at Pennsylvania State College, effective early in 1953. Dr. Shaler was born in London, England, on July 8, 1917. After attending schools in Belgium and Switzerland, and graduating from Hotchkiss School in Lakeville, Conn., he entered Massachusetts Institute of Technology. He received the degree of bachelor of science in physics in 1940, worked briefly in astrophysics and then served in various capacities in the metallurgical industry in South Africa. There, in 1943, he became a director of Industrial Railways Equipment Co. (Pty.), Ltd., whose cemented-tungsten-carbide plant he constructed and operated for two and a half years. Returning to M.I.T. at the end of 1945, he received the degree of doctor of science in metallurgy in 1947 and was appointed assistant professor. From September 1950 until December 1951 he served as scientific liaison officer with the Office of Naval Research, European branch. In July 1951 he became associate professor at M.I.T. and has served in that capacity until his present appointment. Dr. Shaler is vice-chairman of the Board of *Acta Metallurgica*, member of the American Institute of Mining and Metallurgical Engineers, the British Institute of Metals, the British Iron and Steel Institute and the Société Française de Métallurgie. He was awarded the Singer-Polignac Medal in 1939 and the Raymond Memorial Award of the A.I.M.E. in 1951. His publications include books and papers on astrophysics and metallurgy.



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Personals

John R. Shepard has been discharged from active duty with the Army and is now employed as a metallurgist with Pesco Products Div., Borg-Warner Corp., Bedford, Ohio.

H. C. Cole, formerly district manager for Latrobe Steel Co., Latrobe, Pa., now owns and operates Associated Tool & Steel Co. with offices at East Hartford, Conn., and Providence, R. I.

Donald L. Moore has joined General Electric Co. at Lockland, Ohio, as a technical engineer with the aircraft nuclear propulsion project which is under contract to the Atomic Energy Commission and the Air Force.

John H. Sibbison, Jr., has been appointed sales engineer for American Fire Clay & Products Co., Canfield, Ohio, after resigning as chief metallurgist for Superior Foundry, Inc., Cleveland. He will contact foundries in four states for his present company.

John T. Ballass, who recently graduated from Missouri School of Mines with an M.S. degree in metallurgical engineering, has accepted a position with Whitlock Mfg. Co., Hartford, Conn.

Robert Erickson, formerly general plant manager of the RCA radio and television plant at Camden, N. J., was recently appointed vice-president in charge of operations of Daystrom Instrument Div., Daystrom Inc., Archbald, Pa.

Robert L. Gates has been appointed plant metallurgist for the Wooster Div., Borg-Warner Corp., Wooster, Ohio. He was formerly research engineer for Thompson Products, Inc., Cleveland.

Richard J. Quigg, a recent graduate of Virginia Polytechnic Institute, is now with the titanium metal group of pigments division, E. I. du Pont de Nemours & Co., Wilmington, Del.

Roland D. Block has been named plant metallurgist for Alten Foundry & Machine Works, Inc., Lancaster, Ohio. He was previously assistant plant metallurgist, National Malleable & Steel Castings Co., Cicero (Ill.) Works.

Arthur J. Opinsky has joined the theoretical metallurgy section, central engineering metallurgy, Sylvania Electric Products Inc., as a senior engineer.

Davis S. Fields, Jr., has resigned as physical metallurgist at Watertown Arsenal and is now a research assistant and graduate student at Massachusetts Institute of Technology.

Albin B. Charneski has left Battelle Memorial Institute and is now employed by North American Aviation as an analyst in the production development laboratory.

Peter Patriarca is now materials engineer, Rome Air Development Center, Griffis Air Force Base, Rome, N. Y.

Charles W. Smith, formerly development manager of Armzen Co., has accepted the position of general manager, Rodney Mfg. Co., New Bedford, Mass.

Donald A. Wruck, who recently obtained a degree in metallurgical engineering from the University of Wisconsin, has entered active duty in the Air Force and is presently assigned to the University of Illinois for graduate study in metallurgical engineering.

Personals

T. E. Schroeder has become affiliated with Sargeant & Wilbur, Inc., Pawtucket, R. I., as chief engineer of the heavy furnace division.

Howard E. Hartner has accepted a position as principal metallurgist at Battelle Memorial Institute, Columbus, Ohio. He was formerly with Hitchiner Mfg. Co., Inc., Milford, N. H.

S. Tilles has been appointed visiting professor in industrial engineering at Delft University, The Netherlands.

Adolph I. Snow, recently an instructor at the Institute for the Study of Metals, University of Chicago, is now physical chemistry section leader at Sinclair Research Labs., Harvey, Ill.

Guinn E. Metzger is in London to begin a year of study under a Fulbright grant, as a graduate student in metallurgy at the Royal School of Mines, Imperial College, University of London.

Harry I. Askew, Jr., has joined Peninsular Steel Co., Detroit, as a sales and service engineer.

Gene R. Pendl, who recently graduated from Notre Dame University, is employed as junior metallurgical engineer at Bendix Products Div., Bendix Aviation Corp., South Bend, Ind.

William J. Murphy, who was formerly metallurgist with General Electric Co., Lynn, Mass., is now instructor in metallurgy, department of metallurgical engineering, Lehigh University.

Karl H. Kalsen is now employed by Square D Co., Milwaukee, as a metallurgical engineer.

Frank W. Ladwig has left St. Louis (Mo.) Steel Casting Co. where he was general manager, and has purchased the Casey Welding Works, Colorado Springs.

S. Langdon Montanye, Jr., formerly chief engineer of Eaton Metal Products Co., Denver, is now district manager for Landes, Zachary & Peterson, sales engineers. He maintains headquarters in Salt Lake City.

J. G. Montpetit, who graduated from McGill University last spring, is employed as assistant supervisor for the smelting department, Quebec Iron and Titanium Corp., in Canada.

Personals

Robert V. Fister is a metallurgical engineer in charge of raw material inspection at Western Electric Co., Allentown, Pa.

N. L. Bailiff, recently manager of engineering research for Marley Co., Kansas City, is now project engineer in the industrial and government projects division, Fluor Corp., Ltd., Los Angeles.

Melvin C. Metzger, who was previously chief engineer, Metpro Div., Thompson Products, Inc., Cleveland, is now a metallurgist responsible for the development and production of super strength alloys for high temperature applications at Universal Cyclops Steel Co., Titusville, Pa.

Edmond J. Whittenberger received a D.Sc. degree in metallurgical engineering from Carnegie Institute of Technology in June and then became general supervisor of metals research at South Works, U. S. Steel Co., Chicago.

Theodore E. Hack recently joined Jack & Heintz, Inc., Cleveland, as senior metallurgist.

Charles W. Smith has joined Rodney Mfg. Corp., New Bedford, Mass., as general manager. He has long been associated with metallurgy, both as research engineer and development manager, serving with Armzen Co. and the Armco Steel Corp. In 1949, 1950 and 1951 he was an advisory consultant on rolling and metal processing problems throughout England, France, Belgium, Switzerland and Luxembourg. In his new position he will head a new expansion program and take charge of development of new techniques for metal processing.

R. D. Wasserman, president of Eutectic Welding Alloys Corp., Flushing, N. Y., has been unanimously elected to membership in the Young Presidents' Organization. To be a member a man must have become president, before reaching the age of 39, of an industrial or service corporation doing a minimum of a million dollars in gross business annually, plus other qualifications.

James S. Vanick, research metallurgist, International Nickel Co., Inc., New York, was cited by the Gray Iron Founders' Society at its recent annual meeting for contributions to the gray iron foundry industry.

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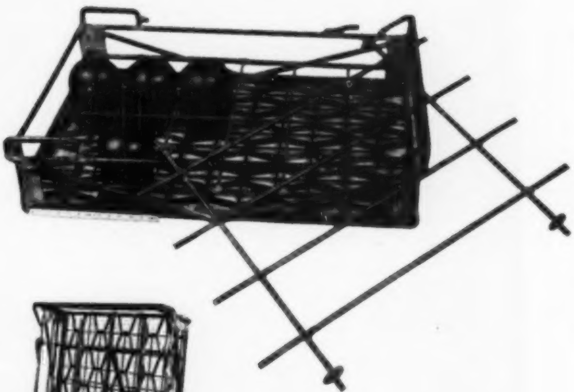
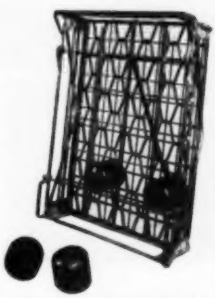
New Equipment For Processing
STEEL SHELL CASES



Before each draw in forming steel shell cases, the material goes thru a cycle of processes while contained in work holders. Details of processes and handling, however, will vary in different plants.

Rolock has built this Inconel fabricated-welded basket to handle the cup and first draw. (A deeper one handles the later draws.) Traveling on rolls and chains, now flat, again on end, suspended and tilted, always heavily loaded, the basket is designed to stand up under an unusual variety of conditions. The cases, separated by dividers, rest on the bottom. Handling two depths of cases, the retaining cover fastens at two heights above bottom. Basket weight 110 lbs., load 290 lbs., ratio exceeds 2½ to 1. By using a high nickel alloy, true conservation of nickel is achieved in cycles of heat, quench, and acid.



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Personals

Andre Guinier, professor of physics at Sorbonne and professor of X-rays, Conservatoire National des Arts et Mètiers, Paris, has been appointed visiting professor of physical metallurgy in the department of mining and metallurgical engineering at the University of Illinois. Dr. Guinier is 1952 Rosenhain Medalist.

Herbert Maier, formerly from the University of Cincinnati, has recently been appointed to the staff of the Gaseous Diffusion Plant at Oak Ridge, Tenn., an atomic energy installation operated by Carbide and Carbon Chemicals Co., a division of Union Carbide & Carbon Corp.

C. Allen Hurt has been appointed package sales department manager at Solar Steel Corp., New York. He has served as sales manager of Solar's Cleveland Division during the past year.

Carl W. Bieser, vice-president in charge of manufacturing at Gruen National Watch Case Co., Cincinnati, Ohio, has been elected a member of the board of directors of Gruen Watch Co.

The Metals Science Club of New York, whose membership is made up of industrial executives and scientists in the field of metallurgy, has announced the election of the following officers for 1952-53: president, **Harry S. Blumberg**, chief metallurgist, M. W. Kellogg Co.; vice-president, **Sam Tour**, chairman, Sam Tour & Co.; secretary, **Howard S. Avery**, research metallurgist, American Brake Shoe Co.; treasurer, **H. M. German**, metallurgical assistant to the president, Driver-Harris Co.

Oscar Pearson, formerly division superintendent of steel production at Gary Works, U. S. Steel Co., has been appointed general superintendent at Duquesne (Pa.) Works. **E. Courtney Sorrells** has been appointed assistant division superintendent of steel production at Gary Works. He was formerly superintendent of the No. 5 open hearth at Gary.

Earle C. Smith, chief metallurgist at Republic Steel Corp., Cleveland, was named vice-chairman of the advisory council for science and engineering of Notre Dame University. The council advises the university on its science and engineering research.

Personals

Howard S. Avery, research metallurgist at American Brake Shoe Co., Mahwah, N. J., was awarded the 1952 Lincoln Gold Medal of the American Welding Society at its recent annual meeting. The Lincold Gold Medal is awarded annually for the paper representing the greatest contribution to the advancement and use of welding. Mr. Avery's paper was entitled "Hard Facing for Impact", and was published in the February 1952 issue of *Welding Journal*. **O. B. J. Fraser**, assistant manager of the development and research division, International Nickel Co., Inc., New York, received the Society's Samuel Wylie Miller Memorial Medal for meritorious achievements in the art of welding. Mr. Fraser was selected for this honor for his studies of field applications and promotion of welding research.

William Owen Philbrook, associate professor of metallurgical engineering at Carnegie Institute of Technology, addressed a group of experts in the iron and steel industry in Latin America, in Bogota, Colombia, last month. Professor Philbrook discussed the acid bessemer process and spoke at the invitation of the United Nation's Economic Commission for Latin America.

Joseph P. Somers has been appointed assistant to the president of Wyckoff Steel Co., Pittsburgh. He formerly was assistant to the vice-president in charge of the company's eastern region in Philadelphia. In his new position Mr. Somers will maintain headquarters at Pittsburgh.

A. E. St. John has been elected president of Alloys & Products, Inc., New York, after serving a year as vice-president. He retains his post as treasurer of the company.

Beresford N. Clarke has been appointed sales engineer in the New England territory for Surface Combustion Corp. He will be engaged in the sales of special furnace heat treat equipment with headquarters in Quincy, Mass.

Walter Batz has accepted a position as research engineer with Jones & Laughlin Research Lab., Pittsburgh. He was formerly a research assistant at the metals research laboratory, Carnegie Institute of Technology.

Atomic Energy in Industry

Reported by M. Eugene Merchant
Assistant Director of Research
The Cincinnati Milling Machine Co.

A SPECIAL conference on Atomic Energy in Industry was held in New York City in mid-October, arranged by the National Industrial Conference Board. Two main questions which seemed to pervade the minds of those present were, "Is atomic power soon to become of significance to industry?" and "Are atomic byproducts of more than passing significance to industry?" The speakers provided varying, but none too encouraging, answers to the first of these, but the answer to the second was a unanimous "Yes".

Power — David E. Lilienthal, first chairman of the U. S. Atomic Energy Commission, pointed out that while nuclear power production was entirely practical at this time, he would not recommend the investment of private capital in power plants at present because of the military limitations of the Atomic Energy Act. Many of the speakers echoed somewhat similar sentiments and dealt with the various legal and economic problems connected with nuclear power.

Of particular interest to metallurgists were the remarks by Lawrence R. Hafstad, Director of the Division of Reactor Development of the A.E.C. He emphasized that three factors limit the selection of metals for use in power reactors, namely, their resistance to radiation damage, their transparency to neutrons and their high temperature characteristics. (These items were considered at length by W. J. Koshuba and V. P. Calkins in "Engineering Principles and Metal Requirements for Atomic Power Plants" in *Metal Progress* for July 1952.) Of the commonly available engineering metals, some of the stainless steels have good properties in these respects, except that their absorption of neutrons is rather high. Exploration of other less common materials revealed that zirconium was excellent in all three respects, provided its common impurity hafnium is *entirely* eliminated. Hafnium has extremely high absorption for neutrons while zirconium is quite transparent to them. As a result, pure zirconium is now being used increasingly as a construction material in reactors and will soon be available to industry. The hafnium byproduct resulting from the purification of zirconium provides, on the other hand, an excellent material for

(Continued on p. 140)

Atomic Energy in Industry

(Continued from p. 138)

reactor control rods because of its high neutron-absorbing ability. It, too, will no doubt become important as an industrial metal in its own right in the not too distant future. (The Atomic Energy Commission is cooperating with the American Society for Metals in presenting a symposium on zirconium and its alloys at the Western Metal Congress in Los Angeles in March 1953.)

In Dr. Hafstad's view there are also difficult metal problems in connection with the heat transfer aspects of the power reactor problem. If water is used as the heat transfer medium between reactor and boiler, then heavy-walled, high-pressure "plumbing" is required which, in turn, means high neutron absorption and a reduced efficiency of the reactor. Therefore, liquid metals seem more desirable and the ones that are at present proving most promising are sodium or sodium-potassium mixtures. Even these, of course, still present severe problems, since they are difficult to handle in themselves, particularly at red heat. Such problems as high-speed pumping of liquid metals at high temperatures are still a source of many headaches. However, Dr. Hafstad assured the audience that although there are many technical problems at the present time, long-range research can be depended upon to solve them. Metallurgists can be expected to play an important role in such research.

Atomic Byproducts — A round table, presided over by William L. Davidson, Director of the Office of Industrial Development of the A.E.C., presented the experiences and viewpoints of five different industrial users of atomic byproducts. S. E. Eaton, Jr., of Arthur D. Little emphasized that the radioactive isotopes (made by irradiating various materials in the nuclear reactor or "pile") are by far the most immediately significant atomic byproducts to date, and went on to illustrate some important uses which have already been made of these in solving industrial problems. One important use of these is as tracers, an application frequently described in the technical and engineering press.

For example, much light has been thrown on the action of brighteners in plating baths by a study of ammonium thiocyanate during silver plating. By using radioactive sulphur as the tracer element in the thiocyanate, it was found that this compound was not plated out on the

(Continued on p. 142)

When a high-strength steel is needed

for severe cold-formed shapes like these bumpers

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GREAT LAKES STEEL CORPORATION
N-A-X Alloy Division
Ecorse, Detroit 29, Mich.

NATIONAL STEEL CORPORATION

Atomic Energy in Industry

(Continued from p. 140)

work by the electric current, as originally thought, but actually formed a protective coating on the surface by physical adsorption, thus preventing the growth of large silver crystals in the true electroplate. Another study — one of the earliest — was made with radioactive sulphur, and proved that the total sulphur content of coke is controlled only by the *total* sulphur content of the coal, and does not depend on the way that sulphur is combined in the coal, whether as pyrite or as an organic compound. Use of high-intensity sources of radioactive cobalt (as well as of other artificial radioisotopes which can be produced at high intensity levels in the nuclear reactor) for economical radiography of castings and structures is another well-known application of atomic by-products, and one growing rapidly in importance. Other uses cited, of a similar more or less universal nature, were the use of artificial radioisotopes to eliminate static electricity in industrial processes, as described in *Metal Progress* only last month by J. D. Graves.

Donald E. Hull, Research Chemist for Standard Oil Co. of Calif., described the use of radioactive piston rings in a test engine, to measure rapidly the effect of different types of motor oils on ring wear. Wear rate can thus be determined within a few hours, draining the oil and measuring its radioactivity due to wear products. Wear testing is transformed in this manner from the slow conventional procedure of many days of running followed by a complete engine overhaul into the rapid procedure of a few hours of running followed by a simple oil drain. A wear testing program which would have cost $1,000,000 and taken 60 years by conventional means has been accomplished in a matter of months and at nominal cost.

William H. Beamer of the spectroscopy laboratory of Dow Chemical Co. described the use of "activation analysis" to determine quantitatively the presence of trace impurities in high-purity magnesium — impurities present in quantities too small to be detected by spectrographic analysis. A sample of the high-purity metal is neutron-irradiated in the reactor, whereupon the impurities present become radioactive and can then be detected by their characteristic radiation. Since such activation analysis is now performed on a service basis by the Oak Ridge National Laboratory, it is of

more than passing significance to the metals industry.

Because as little as one part of impurity in 100,000,000 parts of germanium may adversely affect the electrical properties of that metal for use in transistors,* basic data were needed on the distribution coefficient for impurities in germanium, giving the ratio of solid versus liquid concentration during solidification. J. D. Struthers of Bell Telephone Laboratories found that this information could be obtained rapidly, easily, and with high sensitivity, by making the impurity elements radioactive and determining the relative amounts of these elements in the liquid and in the solid phase by measuring the relative radioactivity. Useful information on the crystallization process in germanium single crystals was also obtained by introducing radioactive antimony into the germanium melt and then preparing radioautographs of sections of the resulting single crystals. The efficiency of the purification processes as the distillation of germanium tetrachloride was also estimated by making the impurity elements radioactive and thereby determining directly their concentration in the final product.

M. E. Merchant of The Cincinnati Milling Machine Co. described the rapid measurement of tool wear and tool life in machining operations. Tool life is the main factor influencing costs in production. However, the testing for improved life is a very lengthy and expensive operation, since a tool must normally be worn to failure — to the end of its life. However, by rendering a cutting tool radioactive by neutron irradiation in the pile, its rate of wear can be measured directly by the radioactivity of the chips within a few seconds of cutting time. The amount of radioactivity of the chips is a direct measurement of how much the tool has worn, since this radioactivity is due only to the tiny particles of material worn from the tool; relative values of tool life can be judged in minutes instead of hours.

*See "The Metal Germanium and Its Use in the Electronics Industry", by Anthony S. Rugare, *Metal Progress*, August 1952.

Effect of Surface Condition on Fatigue Strength*

A SURVEY of information is made of the 159 papers on this subject. The author has cleverly brought out a running story from them regarding surface conditions of steel as they affect fatigue.

The effect of residual stresses is considered, but since effective stress measurements were not always taken, some of the data might be considered more qualitative than quantitative. It is shown that with carefully polished specimens, improvements in fatigue strength have been obtained by carburizing, nitriding, cyaniding, flame hardening, surface rolling, surface pressing and cold working by presetting.

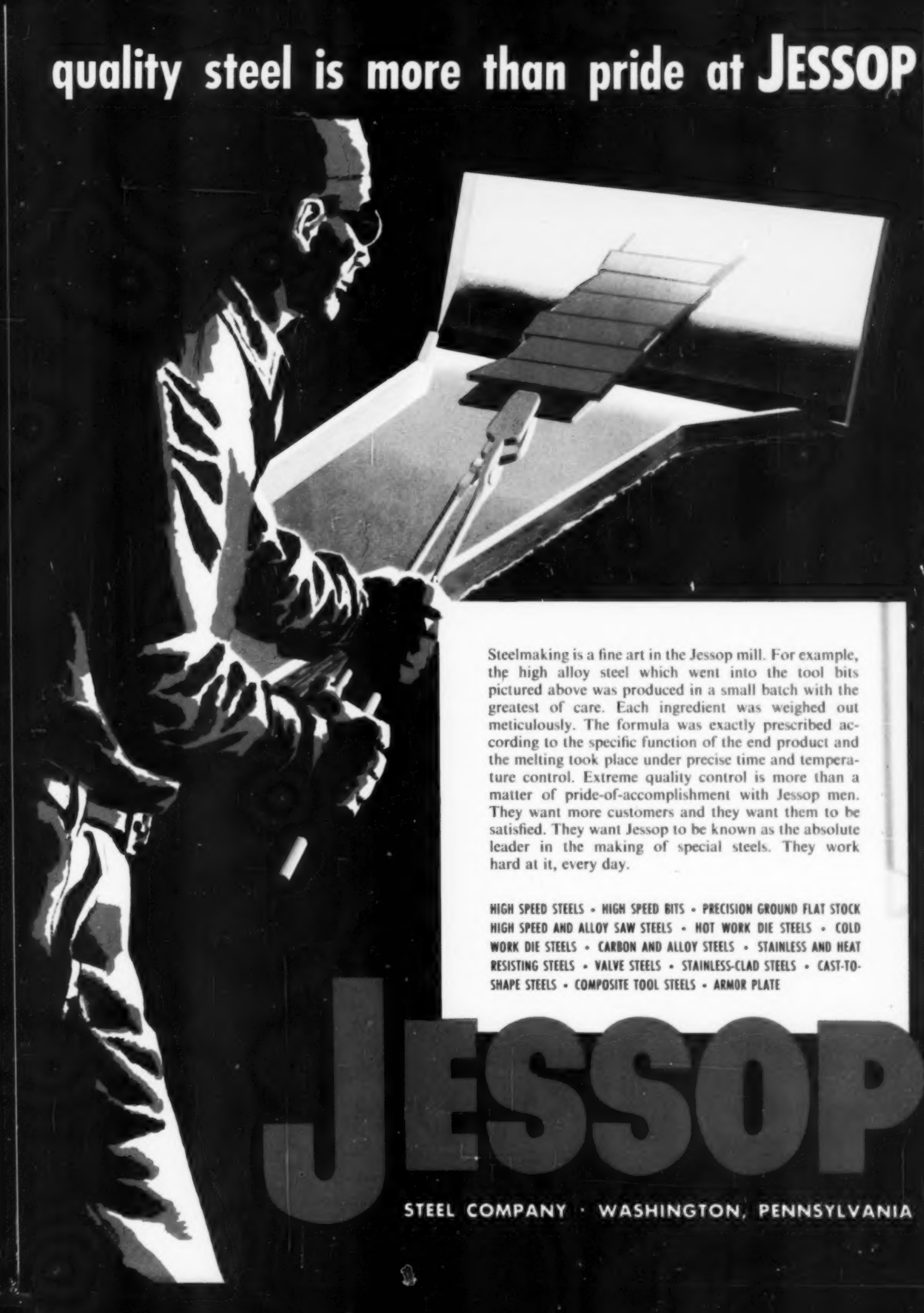
The data presented give considerable evidence to show that the first two methods are the most effective. The statement is made, "Shot-peening has not usually given a very marked improvement of fatigue limit in regard, of course, to polished specimens." This must be due to the author having insufficient data, as it is contrary to fact as we understand it. If the polished specimens are properly peened so as to leave the desired stress pattern, all indications point to an increased fatigue range.

Data given in the tables presented give interesting information regarding polishing the surface, flame hardening, nitriding, and others. The values given in one table create the impression that shot-peening is of little use (most of these results were obtained by laboratory samples tested as a rotating beam). In the paragraphs regarding shot-peening quite the reverse picture is presented. Full-scale components tested show such increases.

The weakening influences on the fatigue strength of steel parts are surface roughness, decarburization, cold straightening, nonferrous coatings, metal sprayed coatings on steel, and acid pickling. Various results are shown for phosphate coatings. All these weakening influences, as shown in the tables, influence the higher carbon, harder steels or hardened alloy steels to a greater extent than low carbon steels or those quite soft. This is in line with industrial experience.

F. P. ZIMMERLI

*Digest of "The Influence of Surface Condition on the Fatigue Strength of Steel", by R. J. Love, *Journal* of the Institute of Metals, Symposium on Properties of Metals, 1952, p. 161-196.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CONSTRUCTION TIME SAVED HERE: Inland Steel Company, Indiana Harbor, Ind., made fast work of slag-pit retaining walls above. Three sets of walls, 500 feet long, resist heat in pits where hot slag is dumped and broken up with huge weights. Concrete made with Lumnite Cement is simply poured in place behind steel piling . . . *reaches service strength in 24 hours or less.* For speed, you can't beat simple monolithic concrete construction with time-saving Lumnite Cement!

OPERATING COSTS CUT HERE: Before the Attalla (Ala.) Pipe and Foundry Co. could use lift trucks for bringing scrap to cupolas, they had to build a ramp that would endure the blazing charges dropped daily by cupolas on either side. At right is their solution—heat-resistant concrete made with Lumnite calcium-aluminate cement. Tough Lumnite-made floors help cut operating costs!

MAINTENANCE REDUCED HERE: 6 months was average life of car tops exposed to quick quenching from 1700° F. at St. Louis (Mo.) Steel Casting Company. But refractory concrete car tops made with Lumnite Cement, such as the one at right, have lasted for several years. Refractory concrete has low volume change to withstand severe thermal shock; takes heat to 2600°F. Helps cut maintenance in furnace and door linings, base pads, foundations and stacks as well.

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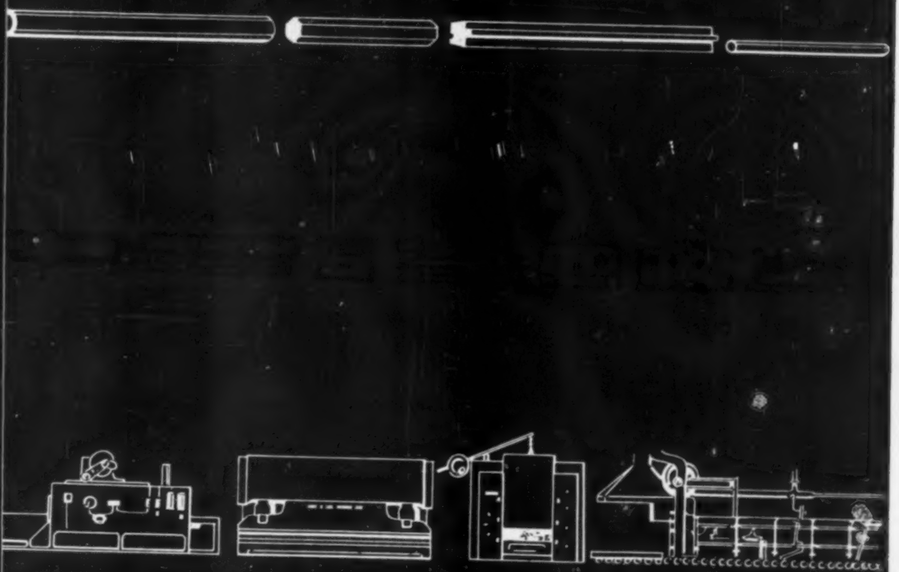

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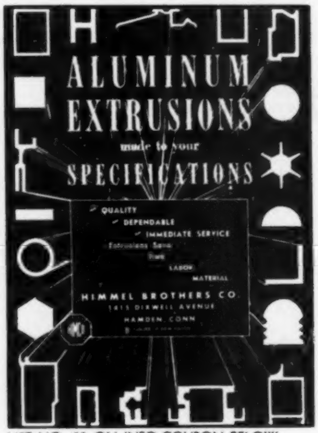

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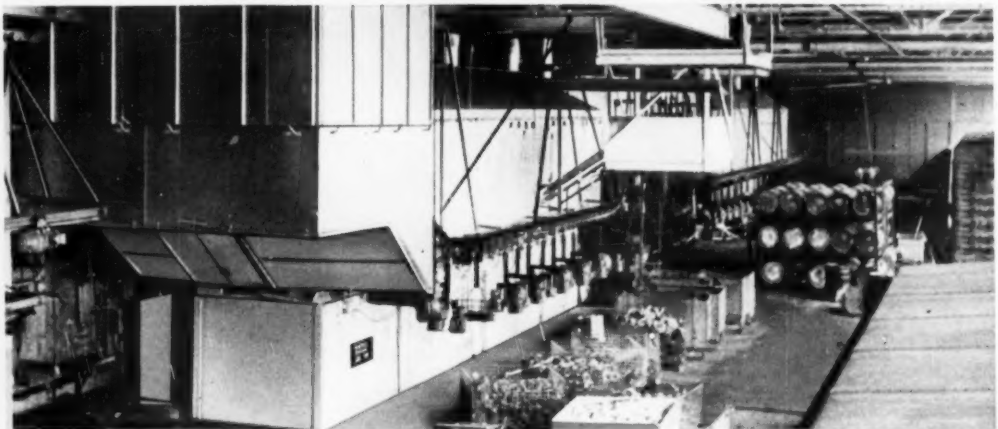

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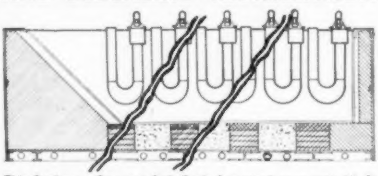

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Making and Using Zirconium*

SINCE AN elaborate and authoritative symposium on zirconium is planned by the U. S. Atomic Energy Commission at the Western Metal Congress in Los Angeles the week of March 23, 1953, this review of published English and American literature (other than the several papers in *Metal Progress* since April 1948) may form a good introduction.

Up till 1946 zirconium was included under the heading of "rare metals". This term is usually associated with the idea of scarcity, yet there is as much zirconium in the earth's crust as carbon. The "rarity" really arose from processing difficulties. Its principal present source is mineral zircon (zirconium silicate) as a byproduct of the treatment of titaniferous black sands. (American production of zircon in 1949 was about 20,000 tons, used primarily for ceramic glazes, refractories and chemicals. About 2500 tons was reduced to master alloys for aluminum and magnesium foundry use and for steel alloying.)

Some idea of the present importance of the refractory applications of zirconia may be gathered from the fact that 28% of the total output of the oxide is used in the refractory industries, and at least 30,000 tons per year of zirconium salts are consumed throughout the world by this industry.

Zirconium Metal is largely made by the Kroll process wherein zircon is heated in contact with excess of carbon in a resistor furnace, thus forming the carbide and carbonitride. Both of these react with Cl to form $ZrCl_4$ at relatively low temperature. Massive $ZrCl_4$ is suspended over a crucible of molten magnesium in vacuo and heated till it sublimes, and comes into contact with the magnesium. Zirconium metal and magnesium chloride are formed rapidly and the material in the crucible finally consists of Zr, $MgCl_2$ and any excess of Mg. The latter two are separated by vacuum melting in another vessel; the Mg drains off as a liquid and the $MgCl_2$ evaporates, leaving behind "Zr sponge", which must be cooled in vacuo to avoid combustion.

The Hunter process, using Na instead of Mg for reducer, has been

(Continued on p. 164)

*Digest of "The Metallurgy of Zirconium, Its Extraction, Fabrication, and Properties", by A. D. Merriman, *Metal Treatment and Drop Forging*, August 1952, p. 365, and September 1952, p. 413.

Making and Using Zirconium

(Continued from p. 162)

used by Titanium Alloys Mfg. Division of National Lead Co., but full details have not been published. Westinghouse Electric Co. has used Ca to reduce the oxide to metal.

Sponge zirconium can be consolidated by powder metallurgy methods, by melting in graphite crucibles, or by forming into sticks (electrodes) which are arc-melted into a water-cooled Cu crucible.

All this must be done out of contact with O_2 or N_2, which are rapidly absorbed by the melt. Even at best the metal contains so much C, O_2 or N_4 that it is brittle and must be refined. (In the event that the Zr must be free from the 1.5 to 3% of its chemical homologue hafnium, the two must be separated — most easily by ion exchange — before any of the above processes start.) Consolidated sponge has been purified of its hydrogen by mildly heating in a vacuum and pumping out the gas as it evolves.

A better way to secure pure zirconium is from sponge by the van Arkel process, also known as the iodide process. Sponge is placed in a chamber with one or more zirconium wires, heated by electric current. After the chamber is evacuated, iodine is introduced. The heat radiated onto the crude metal raises it to a temperature where ZrI_4 is produced which, in the form of vapor, circulates in the vessel. On coming into contact with the hot filament, the iodide deposits pure Zr and liberates iodine which can react again with more crude metal. In this way a massive rod of refined zirconium is built up.

Zirconium appears to stand out most notably because of its superior corrosion resistance and ready workability. In resistance to HCl corrosion, zirconium is close behind tantalum and far superior to the latter in resistance to molten caustic soda. Thus, the most likely future applications for ductile Zr metal appear to be in the chemical industry. Again, like Ta, Zr is unaffected by body fluids, hence should find many uses in the surgical field in the form of plates, wire, and gauze. It is the least toxic of all metals.

The fact that zirconium metal has a very low tendency to absorb slow neutrons, combined with a relatively high melting point (1860° C.) and its ease of formability and corrosion resistance, have made it

(Continued on p. 166)

Making and Using Zirconium

(Continued from p. 164)

a material of much interest in the field of atomic energy. It seems apparent that its use in place of aluminum for the jackets that house the uranium-metal slugs in present-day atomic piles would permit operation at temperatures well above the melting point of aluminum, which is now presumably a limiting factor. Almost all zirconium ores contain hafnium; its separation is mandatory, for the slow neutron-absorption tendency of hafnium is very high. Pure hafnium has formability, corrosion resistance, and a high melting point; this set of properties, combined with its aforementioned nuclear characteristics, suggests its possible value as a material for protective shielding. Metals in the platinum group have roughly similar properties, but only hafnium would be obtainable in ton quantities from readily available raw materials.

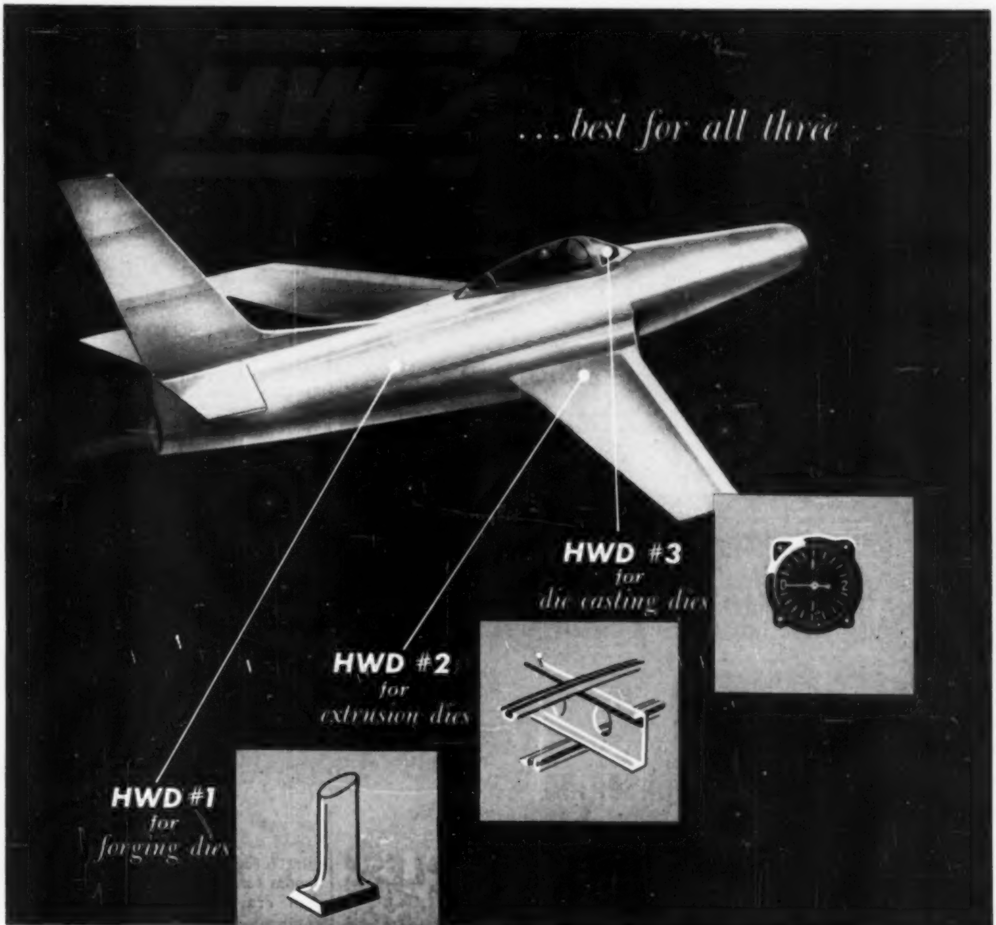
Other Applications—The high resistivity of commercially pure Zr is well above the average for pure metals, but rather less than that of the resistance alloys, Constantan and Manganin. Its temperature coefficient is, however, much lower, and thus shows some advantages over the common, but much cheaper, resistance materials used for electrical measuring instruments.

The emission of electrons from an electrode of a thermionic valve caused by its bombardment by free electrons is known as secondary emission. Zirconium's coefficient of emission is very small. Hence, when the grid of a valve is made of zirconium it acts as an emission inhibitor.

It is considered that when Zr is available in sufficient quantity it will displace tantalum in many of its present uses. The anticipated lower cost and the much lower specific gravity will also be factors of importance that will tend to favor its extended use.

An enormous amount of work has been done on the strengthening of Zr by a modest addition of other alloys. Studies of many of the binary systems have already been published. However, if any very strong, ductile, corrosion and heat resistant alloys with low neutron absorption have been discovered, it is more than likely that they are held secret by the Governmental Commissions which are interested in nuclear reactors and atomic powered engines.

E. E. T.



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The Low-Temperature Cooling Rate Embrittlement of Welds*

THE AUTHORS have rounded out their previous published works on low-temperature cooling rate embrittlement by reporting in this paper the results of tensile, fatigue and impact tests on similarly embrittled welds, and comparing them with the previous results from notch bend tests; conclusions are drawn from the data as a whole. The steel was ¾-in. plate from the same heat used in the previous tests. All welding was carried out with manual electrodes of the E6010 and E6016 types. In addition, the effect of testing temperature and the detection, appearance and distribution of microcracks are discussed.

Bend Tests — The notched bend specimen consisted of a centrally placed weld bead on a ¾ x 4 x 9-in. plate with a center transverse U-shaped groove of 1/16-in. radius cut across the entire width of the specimen to a depth 0.020 in. below the plate surface. Tests were carried out four days after welding. The notch-bend tests reported previously were carried out at −100° F. To determine the effect of testing temperature, certain of the tests were repeated at 70° F. It was found, in general, that the indications of embrittlement were nearly as severe as had been noted at −100° F. In the tests at −100° F., complete and abrupt fracture of all specimens was precipitated by the first cracking of the weld. In the room temperature test, the first sizable crack (or the growth of a crack entirely across the weld) was taken as the criterion of weld failure.

Effect of Postheating — The performance of fissured welds was not greatly benefited by postheating up to 1650° F. (air cool). What benefit there was appears to have been associated with resistance of the weld metal to crack propagation rather than to resist crack initiation.

Tensile Tests — The 9-in. welding bead was deposited on the longitudinal center line of a ¾ x 4 x 18-in. blank, the test section being milled to a 2-in. width after welding. The weld crown was not removed. Seven groups of welds were tested. The welds with E6010 and E6016 were tested in the air cooled and water

(Continued on p. 170)

*A digest of "Microcracks and the Low-Temperature Cooling Rate Embrittlement of Welds", by A. E. Flanigan and M. Kaufman, *Welding Research Supplement*, Vol. 30, December 1951, p. 613s-622s.

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The Low-Temperature Cooling Rate Embrittlement of Welds

(Continued from p. 168)

(70° F.) quenched conditions, and the same conditions for E6010 were tested after postheating for 3 hr. at 1150° F. (air cooled). The seventh group tested consisted of E6010 welds laid down on plates cooled to −100° F. in a box chilled by dry ice and replaced in the box following welding.

The results of the nonpostheated E6010 weld tensile tests clearly indicate the embrittling influence of microcracks under conditions of direct tensile loading.

Both groups of postheated E6010 welds benefited from the treatment. The results of the water quenched, postheated weld tests were not as good, however, as of the air cooled welds. Results of the water quenched E6016 weld tests were not inferior to the air cooled welds.

It is of interest to note that in the air cooled, postheated E6010 welds and in both groups of E6016 welds, the fracture was instantaneous across the whole section, whereas, in the other welds tested, the fracture originated in the weld and was arrested outside the weld. It is also of interest that only the former welds were characterized by low hydrogen content and the absence of microcracks.

Fatigue Tests — Two groups of weld-metal fatigue specimens were tested in a 10,000-rpm. rotating cantilever fatigue testing machine. Only the first group contained microcracks. The presence of microcracks has a strongly adverse effect on the fatigue strength of the welds. Peculiarly, the sound weld-metal specimens exhibited a higher fatigue strength than specimens cut from the parent plate, their strength at 5×10^6 cycles being 44,000 and 32,000 psi., respectively.

Notch Impact Tests — Impact specimens were machined from transverse sections taken across E6010 bead-on-plate specimens. The geometry of the test specimen was that of a half-thickness Charpy specimen containing a half-depth Izod notch located entirely in the weld metal. This choice of geometry caused the weld to extend 40% of the way through the region under the notch. The specimens were broken in a Charpy-type testing machine at a hammer energy of 110 ft-lb. Testing temperature ranged from −100 to 75° F. *(Continued on p. 172)*

The Low-Temperature Cooling Rate Embrittlement of Welds

(Continued from p. 170)

Three groups of specimens were tested, two of which contained no microcracks; these comprised E6010 welds air cooled, E6016 and E6010 welds that were quenched in 70° F. water. The adverse effect of microcracks is clearly evident from the results of the tests.

Microcracks — Two welds, more typical of general practice than the test welds, were made with $\frac{3}{16}$-in. E6010 electrodes and were found to contain numerous microcracks. These welds were a 70° double-V, six-pass butt weld in ¾ x 9 x 18-in. plate (interpass temperature 70° F.) and an intermittent fillet weld consisting of 3-in. beads on 9-in. centers joining two long pieces of ¾ x 4-in. plate. Both welds were air cooled.

Multipass welds were made with E6016 electrodes and examined for microcracks. This test confirmed results by Rollason and Roberts (*Journal* of the Iron and Steel Institute, October 1950) that the first three passes are free from microcracks but the later passes exhibit a number of them. One is led to suspect a significant build-up of hydrogen in the later passes of "low hydrogen" multipass welds as these authors suggest.

It has been the experience of the authors that microcracks are most conveniently detected on sections which have been electrolytically polished but not etched. Perchloric acid–acetic anhydride and chromium trioxide–acetic acid solutions have been used as electrolytes. The microcracks become more prominent with longer periods in the polishing cell.

The number of microcracks per unit area was found to vary with the orientation of the section; as an example, the middle inch of a 9-in. E6010 weld exhibits about five fissures per transverse section and about 75 fissures for the longitudinal inch of section; while on a longitudinal plane parallel to the surface of the plate, about 600 fissures are found for the inch of section.

The authors have observed that the fissures tend to concentrate in the interior of the weld metal and seldom, if ever, occur in regions near the external surfaces or the fusion line. Such a distribution supports the belief that hydrogen concentration is a factor of prime importance in the formation of microcracks. Further, due to this observed dis-

(Continued on p. 174)

The Low-Temperature Cooling Rate Embrittlement of Welds

(Continued from p. 172)

tribution, it is conceivable that misleading results may be obtained from notched specimens if the notch is placed in a fissure-free region.

Borderline Cooling Rates — Consideration of a plot of bend angle at specified failure condition versus weld-bead length (on $\frac{3}{4}$ x 4 x 9-in. plate) shows an abrupt transition in ductility in the neighborhood of 4-in. weld-bead length. In this area, both low and high values of ductility were obtained. Microscopic examination revealed no microcracks in the 4-in. welds and it seemed that the embrittlement was occurring in the absence of microcracks.

It was known from earlier tests that, in the absence of microcracks, the fractures ordinarily tended to originate in the rough surface of the weld on unnotched specimens. Tests were made on borderline (4-in.) welds and it was found that the first fractures originated in the interior precisely in the region where microcracks would have been expected had they been discernible. Undetected microcracks may have been present or the area may have been predisposed to the formation of microcracks upon straining. Tests on postheated 4-in. welds are to be carried out to investigate the latter supposition.

Future Work — As already noted, more work will be carried out with relation to the borderline cooling rates. Also, work designed to give a clearer understanding of the roles of hydrogen, nitrogen, retained austenite and certain observations bearing on the mechanism of fissuring will be reported in a later paper.

S. A. AGNEW

Bismuth Thermocouples for Low-Range Operation*

APPEARANCE on the market of fine thermocouple wire of ductile bismuth and bismuth alloy has thrown into practical focus its usefulness for sensitive temperature measurement in the range from below zero to 250° F. While its high resistance change with temperature and low thermal capacity have been recognized in a laboratory way, such

(Continued on p. 176)

*Digest of "Bismuth Thermocouples", by Alvin B. Kaufman, *Instruments*, Vol. 25, June 1952, p. 762.

Bismuth Thermocouples

(Continued from p. 174)

factors as high cost, brittleness with aging and commercial nonavailability have kept bismuth beyond the realm of thermocouple application.

Of all the ductile metals, bismuth has the highest negative thermocouple voltage. A proprietary companion alloy, named by its supplier as bismuth alloy "B", reportedly has the highest positive thermocouple voltage of the ductile metals. Together they give an output of 0.04088 millivolts per degree F. from −114 to 350° F. (top limit).

Bismuth can absorb only one third the heat that copper does, and transmits that heat at 1/80th the rate of copper. This low capacity and conduction mean practically instantaneous response in thermocouple usage. Over-all accuracy, especially with items of low thermal mass, is therefore improved.

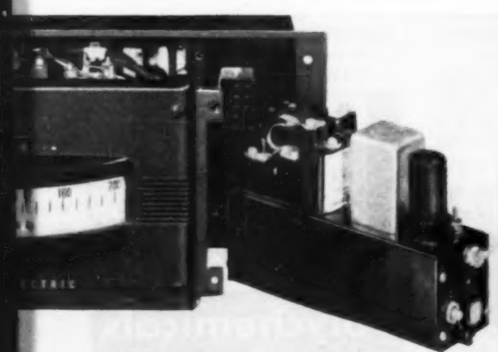
Some limiting factors should be noted. Bismuth wire has pronounced change of resistance when subjected to a magnetic field, as well as to change of temperature. It also has the highest Hall coefficient of all ductile metals. These characteristics generally limit the use of bismuth couples to manual and automatic-balancing potentiometers. A direct-reading meter is not advisable unless leads are maintained at ambient or hot-junction temperature, or each installation is calibrated separately.

In making the junction with bismuth thermocouples, no solder or flux can be used, since they make the junction unstable metallurgically and electrically. For mechanical support, the alloy "B" is wound around the ductile bismuth and fused with a clean soldering iron at 480° F. The alloy has a melting point of 420° F., while that of the ductile metal is 520° F. A mechanical connection is recommended for the cold junction.

While not ductile in the same sense as is copper, bismuth wire can be wound on its own diameter and can be bent rather sharply at room temperature. Flexing will cause failure, as will continuous vibration, so the wire should be held by some thermosetting plastic.

Output of the bismuth couple can be used to operate holding coils and other mechanisms, or for direct application to the grid of tube amplifiers or thyratron-controlled power sources. It is not suited for the operation of relays or other power devices.

A. H. Allen



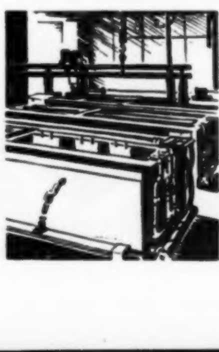
Critical Points

(Continued from p. 70)

tually building up a sizable rod of quite ductile metal. Both methods are costly; titanium sponge is currently quoted at \$5 per lb., bars at \$6 to \$12. Obviously, plants using these unit processes can be multiplied almost indefinitely, but in all probability will not reduce the costs drastically.

Some possibilities for new processes were suggested by R. S. Dean, consulting engineer (for years chief metallurgist of the Bureau of Mines). He noted that oxygen is so tightly bound to titanium that metallic calcium is about the only metal which will reduce it, and the reaction does not go entirely to completion. Herein lie three major problems: Remove the CaO from the reduced titanium; regenerate the calcium as metal; free the titanium from traces of unreduced TiO_2 or oxide in solution. In Dr. Dean's opinion a more likely source of cheaper titanium would be in the chlorination of the titanium to the lower chloride $TiCl_2$. This is reducible by many commercial metals, the action is complete, and requires (in general) only half the reagent which $TiCl_4$ uses up in the Kroll process. In fact, $TiCl_2$ can be dissociated by heat alone, half appearing as Ti, the other half as $TiCl_4$. Titanium can also be reduced electrolytically from a molten bath of alkaline chlorides in which titanium salts are dissolved. High current efficiencies can be obtained, but the product is granular or a coarsely crystalline mass. Possibly massive and less expensive titanium will eventually result from this process, or molten titanium by a reduction method similar to the pioneering method of 1906.

Cheap titanium obviously will not be come by easily. As Prof. Hunter remarked, we must have radically new methods, and since there is ordinarily a lapse of a decade from research to tonnage production, the question is "When do we start?"



Diffusion of Hydrogen at Elevated Temperatures*

A DESCRIPTION is given of a carefully conducted study of hydrogen diffusion in 10 different iron alloys in the temperature range of 390 to 1830° F. (200 to 1000° C.) and with pressures varying between 760 and 800 mm. on the inlet side (P_1) with standard pressure (760 mm.) (P_2) on the outlet side and also with outlet pressure (P_2) reduced below standard.

A previously derived equation by Richardson from the study of diffusion of hydrogen through platinum leads to the following expression:

$$P = K^{1/l} P_1^{1/2} \exp(-E/RT)$$

where K is a constant, P_1 the ingoing pressure, l membrane thickness, T absolute temperature, R gas constant, and E the activation energy of permeation, when the outgoing pressure P_2 is 0. At constant temperature the equation reduces to:

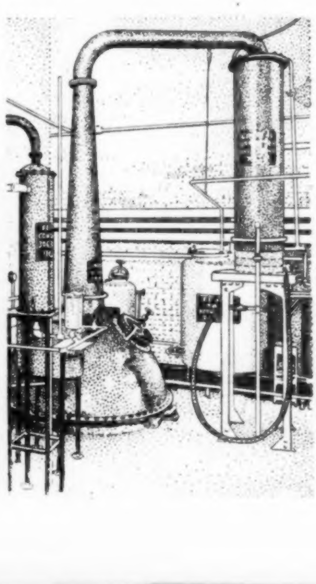
$$P = K^1(P_1^{1/2} - P_2^{1/2})$$

This expression was found to be reliable at constant temperature and high pressure, while at low pressures the departure from the law was found to be greater the lower the temperature.

Test specimens measuring 0.330 in. diameter and 3⅝ in. long were

(Continued on p. 182)

*Digest of "Diffusion of Hydrogen in Iron and Iron Alloys at Elevated Temperatures", by P. L. Chang and W. D. G. Bennett, *Journal* of the Iron and Steel Institute, Vol. 170, March 1952, p. 205-213.



Diffusion of Hydrogen at Elevated Temperatures

(Continued from p. 180)
drilled to give a hole ¼ in. in diameter and 3¼ in. deep. An austenitic stainless steel tube, 0.888 in. o.d. and 0.555 in. i.d., was welded to the specimen forming a sheath with an annular space outside the specimen for the escape of the diffusing hydrogen. Repeated testing of the evacuated gas from this annulus always showed over 98% hydrogen. A platinum – platinum-rhodium thermocouple wired to the outside of the stainless sheath controlled and recorded the temperatures during the tests.

Ten different materials, all having less than 0.05% carbon, were tested. Significant elements in the samples are given in the tabulation.

SAMPLE	% CR	% NI	% MO
A*	—	—	—
2	1.38	—	—
3	2.51	—	—
5	4.25	—	—
11	—	0.94	—
12	—	1.87	—
15	—	4.36	—
21	—	0.19	0.98
22	—	0.20	2.36
27	—	0.21	10.36

*Ingot iron.

Phosphorus, sulphur, silicon, and manganese were all of normal ranges for alloy steels.

A series of tests on each alloy under constant pressure (P_1 about 760 mm.), (P_2 about 0 mm.) were made at temperatures between 390 and 1830° F. After welding and assembling the test piece and sheath in the apparatus a vacuum pump reduced the pressure in the annulus to 0.0002 mm. of mercury. The specimen was then heated to 1830° F., degassed for 1 hr., after which it was soaked in hydrogen for 2 hr. After this the system was pumped out while the inlet pressure was maintained at 1 atmosphere of hydrogen. A series of graphs in which the log of P is plotted against 1/T show the straight line relationship which exists between these two variables. From the slope of these curves the activation energy, E, in the equation was calculated. This was 17,800 cal. per g-mol. for ingot iron, 18,500 to 20,600 for the 1.38 to 4.25% Cr alloys, 18,900 for all of the nickel alloys (1 to 4.36% Ni), and 16,500 to 15,300 for the molybdenum alloys (1 to 10.36% Mo) in the alpha structure temperature range. In the gamma region the activation energy was about 37,400 cal. per g-mol.

In the nickel and molybdenum alloys the permeation rate was prac-
(Continued on p. 190)

Diffusion of Hydrogen at Elevated Temperatures

(Continued from p. 182)

tically the same as for ingot iron; the chromium alloys had a very pronounced effect in reducing the diffusion rate in the alpha range below 1830° F. These results are:

1. In the gamma range the rate of permeation is not appreciably affected by the presence of Cr up to 4.2%.

2. In the alpha range the permeation rate is greatly reduced with increasing chromium and at 1110° F. is ten times smaller in the 4.25% Cr alloy than in ingot iron.

3. The low temperature deviation disappears in the higher Cr alloys above 1.38% Cr.

4. Apparent activation energy in the alpha range is increased slightly by Cr additions.

A second series of tests were run at constant temperature: *(a)* with P_2 at vacuum and varying the inlet pressure P_1, and *(b)* with P_1 about 760 mm. and varying outlet pressure P_2 above vacuum levels. In every case the graphs showed a straight-line relationship between diffusion rate and the differential pressures according to the equation:

$$P = K''(P_1^{1/2} - P_2^{1/2})$$

for constant temperature condition.

Mathematical analyses of the various isobars and isotherms obtained in this investigation enabled the authors to derive a generalized equation:

$$P = (K_1 P_1^x - K_2 P_2^y) \cdot (1 - S) \exp(-E/RT)$$

where K_1 and K_2 are constants, and x, y, and S are functions of temperature. Richardson's equation for platinum may be regarded as a special case of the above in which

$$K = K_1 = K_2,\ x = y = \tfrac{1}{2},\ S = 0.$$
$$\text{Therefore } P = (\sqrt{P_1} - \sqrt{P_2}).$$

The mechanism of diffusion is assumed to take place by *(a)* dissociation of the gas molecules at the metal surface and *(b)* by establishment of gas concentrations at the high and lower pressure surfaces which are in equilibrium at each surface. The first is verified by the experiments but the second is only valid if the phase boundary processes (absorption and solution) are rapid, compared to diffusion through the metal.

E. C. Wright

Effect of Machining and Grinding on Metal Surfaces*

PURPOSE OF THIS PAPER is to describe how the physical, metallurgical and geometrical condition of a machined or ground surface can be affected by such factors as the cutting conditions, metal being cut, the material of which the tool is made and the condition of the cutting surface of the tool. The investigation was primarily concerned with turning and grinding, but drilling, honing and superfinishing operations are also referred to briefly.

In the study of turning, the authors evaluated surface roughness, work hardening, residual stresses and chip-shape for a variety of machining conditions (depth of cut, feed and speed), work (mild steel, leaded 60-40 brass and duralumin)

(Continued on p. 192)

*Digest of "The Influence of Machining and Grinding Methods on the Mechanical and Physical Condition of Metal Surfaces", by Peter Spear, Ian R. Robinson and K. J. B. Wolfe. *Journal* of the Institute of Metals, Symposium on Properties of Metals, 1952, p. 59-100.

Effect of Machining and Grinding on Metal Surfaces

(Continued from p. 190)
and tool materials (high-speed steel, cemented carbide and sintered aluminum oxide ceramic). They found that the work hardening was negligible for duralumin, slight to moderate for brass (depending on the tool material) and pronounced for mild steel, the surface hardness in the last increasing rapidly with depth of cut. The magnitude of the residual stresses, determined qualitatively from the diffuseness of X-ray diffraction lines, was in general agreement with the degree of work hardening. The surface finish depended in a complex manner upon the combination of work metal, tool material and work speed that was used.

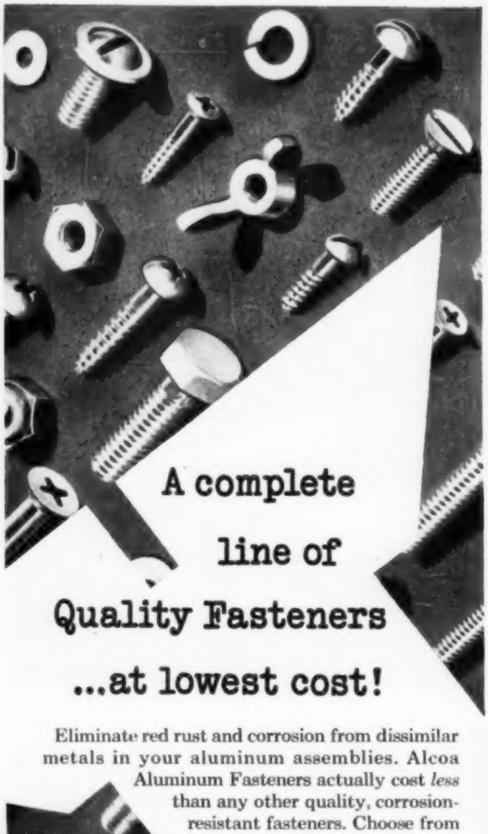
The data indicate that the condition of a surface that is machined with a ceramic tool is within the range of conditions encountered when carbide and high-speed steel tools are used. However, it was observed that ceramic tools had a greater tendency to burnish the surface, especially for very shallow cuts. No information is presented on relative tool-life, so that it is not possible to judge on the basis of this study the real utility of ceramic tools under production conditions.

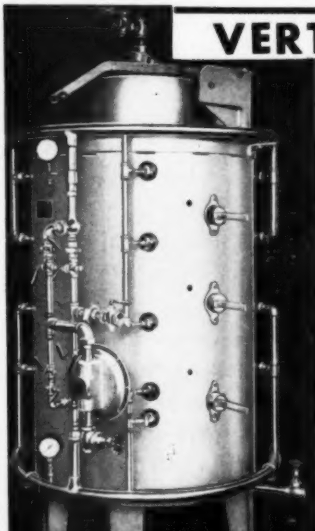
The other major portion of the investigation dealt with the effect of grinding practice upon the surface condition of high-speed steel turning tools. Wheels of different grit sizes, ranging from 36 to 220, were used both wet and dry, the grinding fluid being a light grinding oil. X-ray diffraction studies showed that in most instances several per cent of retained austenite formed as a result of the grinding operation. Although no mention is made of this in the paper, the austenite could have formed only because the tools were badly burned by excessive grinding heat, which was sufficient to bring at least some portions of the surface above the transformation range.

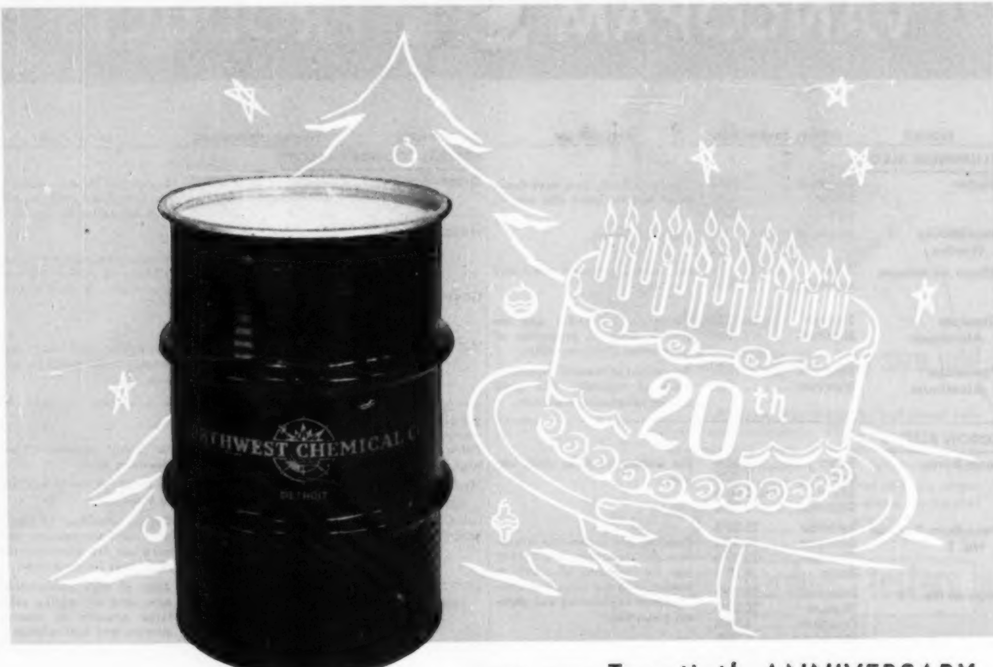
Experience indicates that the immediate quenching of the austenitized surface by the cold underlying steel must have resulted in the formation of a rehardened layer containing the small percentages of retained austenite that were observed. The depth of rehardening, which was neglected by the authors but which is far more significant than the amount of retained austenite, could have been detected without difficulty by metallographic examination.

Inasmuch as proper grinding practice with medium grit wheels does not result in the austenitization of the tool surface that was observed by the authors, their data cannot be used as a basis for selecting the best grit size or deciding whether to grind wet or dry.

A consequence of their preoccupation with retained austenite to the exclusion of any mention of rehardening and overtempering is that the authors associate poor tool life entirely with the amount of retained austenite. Granting that this constituent undoubtedly has some unfavorable effect, it is likely that the major effect is due to the presence in the surface of a far larger amount of brittle, untempered martensite and of softened, overtempered martensite, the latter being in those areas that did not quite reach the austenitizing temperature during grinding. All these factors contribute to the poor tool life associated with unsatisfactory grinding practice. L. P. Tarasov







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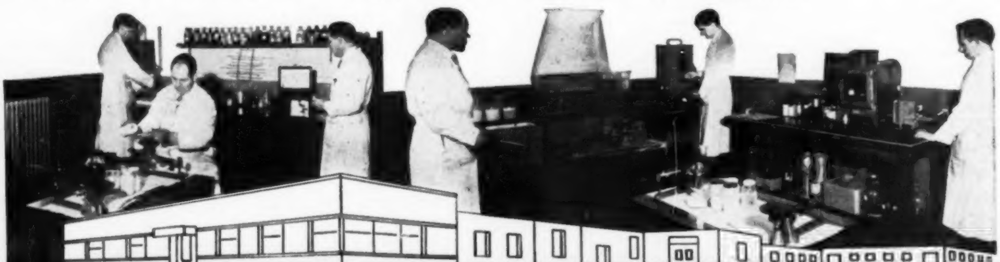

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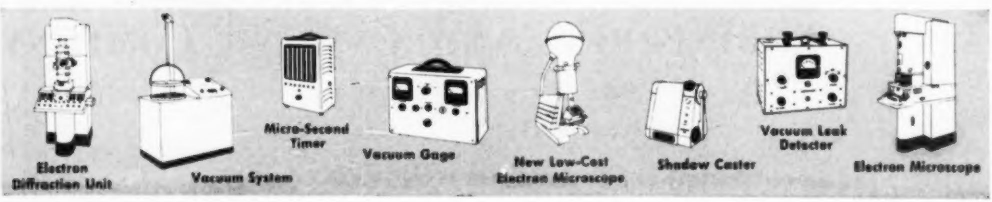

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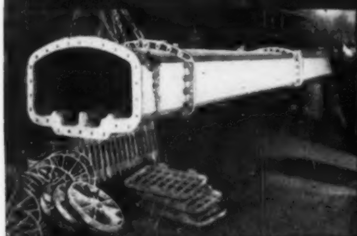

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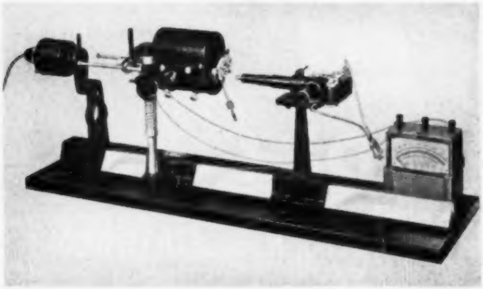

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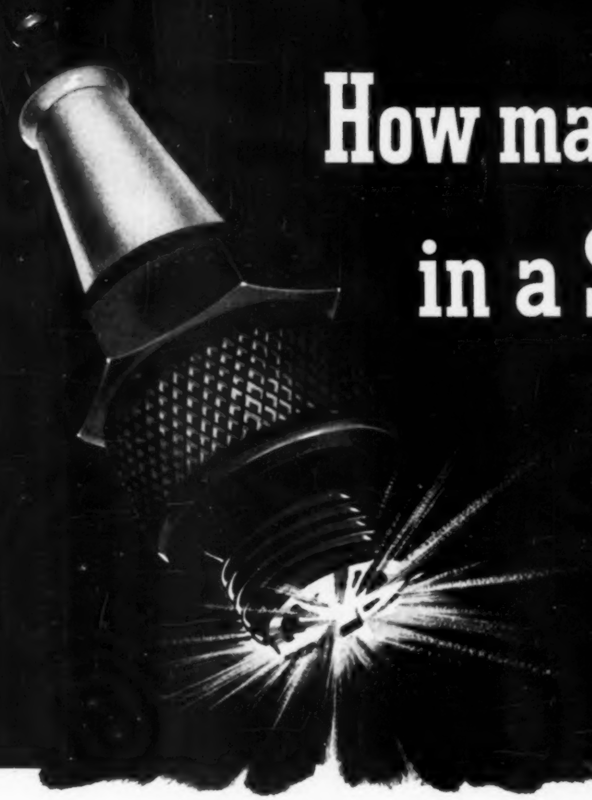

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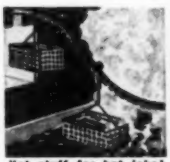

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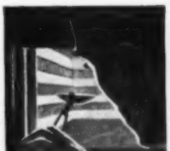

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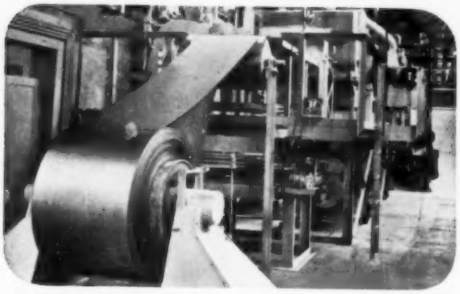

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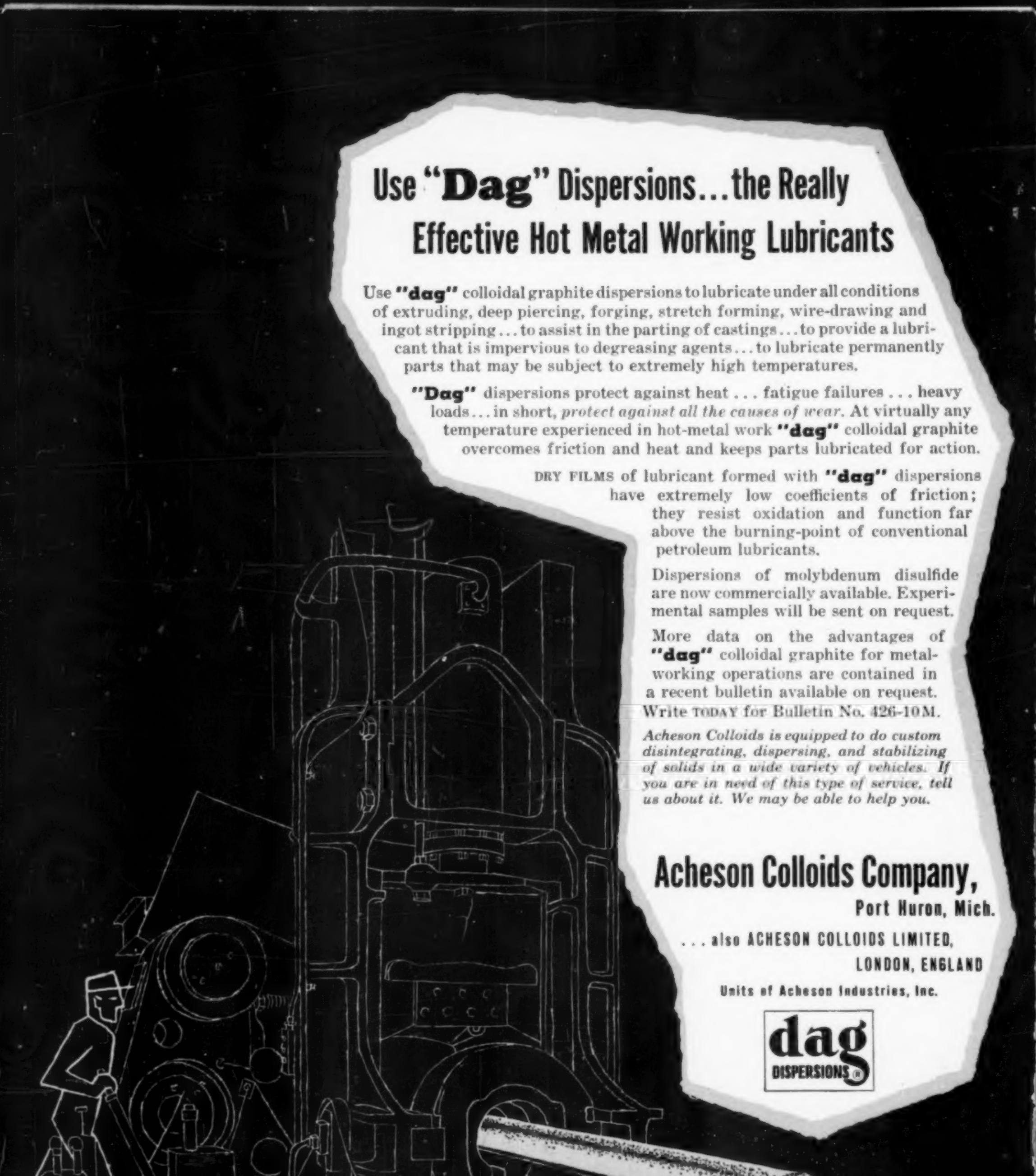
LARGE STRUCTURAL SHAPES up to 90 feet in length are automatically charged into this furnace, carried across the 93 ft. x 26 ft. heating chamber, uniformly heated and discharged thru a spray quench — everything is automatic. Built by The Electric Furnace Co., Salem, Ohio.

BRIGHT ANNEALING WIRE. An EF continuous bright annealing furnace in which the wire is conveyed through the various zones on two parallel rows of bulkhead type trays. This unit has convection cooling and handles 2500 net lbs. of wire per hour. Built by The Electric Furnace Co., Salem, Ohio.



Use "Dag" Dispersions... the Really Effective Hot Metal Working Lubricants
Use "dag" colloidal graphite dispersions to lubricate under all conditions of extruding, deep piercing, forging, stretch forming, wire-drawing and ingot stripping... to assist in the parting of castings... to provide a lubricant that is impervious to degreasing agents... to lubricate permanently parts that may be subject to extremely high temperatures.
"Dag" dispersions protect against heat... fatigue failures... heavy loads... in short, protect against all the causes of wear. At virtually any temperature experienced in hot-metal work "dag" colloidal graphite overcomes friction and heat and keeps parts lubricated for action.
DRY FILMS of lubricant formed with "dag" dispersions have extremely low coefficients of friction; they resist oxidation and function far above the burning-point of conventional petroleum lubricants.
Dispersions of molybdenum disulfide are now commercially available. Experimental samples will be sent on request.
More data on the advantages of "dag" colloidal graphite for metal-working operations are contained in a recent bulletin available on request. Write TODAY for Bulletin No. 426-10M.
Acheson Colloids is equipped to do custom disintegrating, dispersing, and stabilizing of solids in a wide variety of vehicles. If you are in need of this type of service, tell us about it. We may be able to help you.
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DISPERSIONS